NASA Technical Memorandum 100543

AVSCOM
Technical Memorandum 88-B-006

INFLOW MEASUREMENT MADE WITH A LASER VELOCIMETER ON A HELICOPTER MODEL IN FORWARD FLIGHT

Volume III RECTANGULAR PLANFORM BLADES AT AN ADVANCE RATIO OF 0.30

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April 1988

(NASA-TM-100543) INFLOW MEASUREMENT MADE WITH A LASER VELOCIMETER ON A HELICOPTER MODEL IN FORWARD FLIGHT. VOLUME 3: RECTANGULAR PLANFORM BLADES AT AN ADVANCE RATIO OF 0.30 (NASA) 390 p CSCL 01A G3/02

N88-22015
Unclas
0141223

National Aeronautics and
Space Administration

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SUMMARY

An experimental investigation was conducted in the 14- by 22-Foot Subsonic Tunnel at NASA Langley Research Center to measure the inflow into a scale model helicopter rotor in forward flight ($\mu_\infty = 0.30$). The measurements were made with a two component Laser Velocimeter (LV) one chord above the plane formed by the path of the rotor tips (tip path plane). A conditional sampling technique was employed to determine the azimuthal position of the rotor at the time that each velocity measurement was made so that the azimuthal fluctuations in velocity could be determined. Measurements were made at a total of 180 separate locations in order to clearly define the inflow character. These data are presented herein without analysis.

INTRODUCTION

One of the many problems confronting the helicopter aerodynamic community is the lack of a comprehensive database which includes the measurements of the velocities into and through the rotor systems. These measurements are necessary for a more complete understanding of the fluid dynamics associated with the rotor and its thrust/lift producing process, and to provide data for the validation of the rapidly emerging computer codes intended to predict the behavior of this process. One explanation for the lack of available data is the absence, until recent years, of a suitable device for making such measurements. Making measurements in and around a system of rotating blades requires a nonintrusive measurement capability that presents a minimum risk to the systems involved and provides an accurate means of making such measurements. The Laser Velocimeter (LV), which uses high energy light beams to measure velocities, is ideally suited to this task.

The Laser Velocimeter has been successfully used to measure specific areas and localized phenomena within the rotor disk (refs. 1 through 3). In addition, the hotwire anemometer and pressure probes, both having directional measuring limitations, have been employed in similar programs (refs. 4 and 5). This is, however, the first time that a comprehensive program has been undertaken to map the flow into the complete rotor disk. An investigation has been conducted to measure the flow into a representative rotor system as a function of azimuth using a two-component (stream wise and vertical direction) LV system.

NOTATION

A_0	constant term in Fourier series of blade feathering (collective) at $r/R = 0.75$, deg
A_1	coefficient of cosine term in Fourier series of blade feathering, deg
B_1	coefficient of sin term in Fourier series of blade feathering, deg
b	number of blades
C_D	rotor drag coefficient, $D/\rho\ A\ (V_{tip})^2$, nondimensional

C_Q rotor torque coefficient, $Q/\rho\ A\ R\ (V_{tip})^2$, nondimensional

C_T rotor thrust coefficient, $T/\rho\ A\ (V_{tip})^2$, nondimensional

c rotor blade chord, inches

D rotor Drag, positive to the rear

Q rotor Torque, ft-lb

q dynamic pressure, lb/ft^2

r local radius of the rotor system, ft

R rotor radius, ft

T thrust produced by the rotor, lbf

U free-stream component of velocity, positive downstream, ft/sec

U_∞ free-stream velocity, positive downstream, ft/sec

u_i induced component of velocity parallel to the tip path plane (positive flow down stream), ft/sec

V vertical component of velocity, positive up, ft/sec

v_i induced component of velocity normal to the tip path plane (positive flow up), ft/sec

V_{tip} rotor blade tip velocity, ft/sec

Greek

α angle between rotor disk and free-stream velocity (positive nose up), deg

λ inflow ratio normal to Tip Path Plane (positive up), $(U_\infty \sin\alpha + v_i)/V_{tip}$

λ_i induced inflow ratio normal to Tip Path Plane, (positive up), v_i/V_{tip}

μ_∞ rotor advance ratio, $U_\infty \cos\alpha/V_{tip}$

μ inflow ratio parallel to Tip Path Plane (positive down stream), $(U \cos\alpha + u_i)/V_{tip}$

μ_i induced inflow ratio parallel to Tip Path Plane (positive down stream), u_i/V_{tip}

r rotor rotational speed, radians/sec

ψ rotor azimuth measured from downstream position positive counterclockwise as viewed from above, deg

ρ air density, $slugs/ft^3$

θ blade pitch angle at a specific azimuth, $\theta = A_0 - A_1 \cos \psi - B_1 \sin \psi$, deg

$\overline{xx}$ mean values

EXPERIMENTAL APPARATUS

The experimental apparatus used in this investigation included the NASA Langley Research Center 14- by 22-Foot Subsonic Tunnel, the 2-Meter Rotor Test System (2MRTS), and a two-component laser velocimeter system.

The 14- by 22-Foot Subsonic Tunnel is an atmospheric, closed-circuit wind tunnel of conventional design with enhancements for the testing of powered and high-lift configurations (ref. 6). The tunnel is shown in figure 1 and schematically in figure 2. When the test section is configured open, with the walls and ceiling lifted out of the flow leaving only a solid floor and a flow collector at the rear, it can be driven to about 170 knots. This investigation was conducted with the tunnel in this configuration to allow complete optical access to the rotor flowfield produced by the 2MRTS that was mounted on a strut in the forward part of the test section as is shown in figure 3.

The 2MRTS is a general purpose rotorcraft model testing system. The system consists of a 29-horsepower electric drive motor and 90° speed-reducing transmission, a blade pitch control system, and two six-component strain gage balances used for measuring forces and moments on the rotor system and fuselage shell. The four-bladed rotor hub is fully articulated with viscous dampers for lead-lag motion and coincident flap and lag hinges. A more detailed description of the 2MRTS including the ROBIN fuselage can be found in reference 7. The characteristics of rotor blades used in this investigation can be found in table 1. No attempt was made to dynamically scale the rotor blades, rather they were made as stiff as possible to minimize deflection while being tested.

The LV system used in this investigation was designed to measure the instantaneous components of velocity in the longitudinal (free stream) and vertical directions. The LV system is described in reference 8. The system is comprised of four subsystems: optics, traverse, data acquisition, and seeding. The optics subsystem, which is shown in figure 4, operates in backscatter mode and at high power (4 watts in all lines) in order to accommodate the long focal lengths needed to scan the wide test section. The transmitting and receiving optics packages are augmented by a zoom lens system consisting of a 3-in. clear aperture negative lens and a 12-in. clear aperture positive lens. Bragg cells in each of the optical paths provide a directional measurement capability. The velocity measurements are made at a point in space where the four beams cross, called the sample volume. The length of the sample volume (transverse to the flow direction) increases as the sample volume is moved away from the optics assembly. The sample volume is, over the 10- to 20 ft focal length of the system, less than 1 cm long with a near constant diameter of 0.2 mm.

The traverse subsystem provides five degrees of freedom in positioning the sample volume and is controlled by the same computer that is used for data acquisition. Translation of the sample volume in the horizontal and vertical direction is accomplished by displacing the entire optics platform. Translation along the lateral axes is accomplished by displacing the negative lens located in the zoom lens assembly, thus refocusing the sample volume along the axis of optical transmission. The other two degrees of freedom, pan and tilt, are implemented by rotating the final mirror about its vertical and horizontal axis in order to change the direction of optical transmission. The total inclusive range of the traversing system is 7 ft vertically,

transmission. The total inclusive range of the traversing system is 7 ft vertically, 6 ft streamwise, 16.5 ft laterally, and 10° in both pan and tilt. Measurements can be made outside of this envelope by re-positioning the optics platform, which is mounted on wheels to facilitate such relocations. For this study the traversing system was positioned to the right of the test section when looking upstream as shown in figure 5.

The data acquisition subsystem is shown schematically in figure 6 and interfaces with the optical signal processing equipment to receive two channels of raw LV data and up to five channels of auxiliary data. In this investigation four of the auxiliary channels were used for the acquisition of data relative to blade position. Two of the channels (one each for the U and V components) measured the azimuthal position of the rotor shaft and the other two the lead/lag and flapping motion. The system converts the raw LV data to engineering units and determines the statistical characteristics of the acquired data so that the test results can be evaluated during the acquisition process. The raw data which is acquired from the buffer interface device, the data which has been converted to engineering units, and up to 64 parameters which are acquired from the tunnel static data acquisition system are written to magnetic tape for later analysis. The final function performed by the data system is to interface with and control the five degree of freedom scan system.

The seeding subsystem, shown schematically in figure 7, is a solid particle, liquid dispensing system (ref. 9). Polystyrene latex microspheres are suspended in a mixture containing, by volume, 50 percent water and 50 percent ethyl alcohol. The advantage of the polystyrene particles is their low density, high reflectivity, and precise particle size. The size of the particles used in this investigation was 1.7 microns in diameter with a standard deviation of 0.0239 microns. This mixture is pumped to an array of 32 nozzles where compressed air is used to atomize the mixture. These nozzles are mounted on a frame 8 ft wide by 6 ft high which is suspended on cables in the settling chamber of the tunnel. The low vapor pressure of water/alcohol mixture allows it to evaporate as it travels the 85 ft from the settling chamber to the test section. This process provides isolated single particles in the flow field whose velocities are measured as they pass through the sample volume, from which the local fluid velocity is inferred.

ERROR ANALYSIS

The overall LV system error is obtained by summing the error of all of the components that contribute to an error in the velocity measurement. The error sources are summarized in the table below, and are defined in refs. 10 and 11. The result in a bias error of -0.81 percent to 1.82 percent and a random error of 1.12 percent. Taking the square root of the sum of the squares of these gives a total system error of 1.38 percent to 2.14 percent (1.76 percnet ± 0.38 percent).

Error source	Bias percent	Random percent
Cross beam angle measurement	0.81	None
Diverging fringes	A	A
Time jitter	N/A	N/A
Clock synchronization	0.51	±0.51
Quantization	A	±0.99
Velocity bias	B	B
Brag bias	B	B
Velocity gradient	B	B
Particle lag	±0.50	B
Total error	-0.81 to 1.82	1.12
A NOT MEASURED B NEGLIGIBLE		

TEST PROCEDURES

Measurements were made at azimuthal increments of 30° from $\psi = 0$, at 3.0 in. (approximately one chord) above the plane formed by the tips of the blades. Measurements were made from radial location of $r/R = 0.2$ to $r/R = 1.1$, with the majority of the measurement locations concentrated toward the outboard portion of the disk. Figure 8 shows the measurement locations superimposed on the rotor disk. During the test the rotor tip path plane was maintained at -4° relative to the free stream by zeroing the blade flapping relative to the shaft and setting the shaft angle to -4°. The operating rotor speed for the test was held at 2113 rpm, the nominal tunnel speed was 187 ft/sec ($\mu_\infty = 0.30$), and the nominal rotor thrust coefficient was 0.0064. Table 2 lists the target flight conditions, and selected parameters acquired during the test. The acquisition process consisted of placing the sample volume at the location to be measured and acquiring data for a period of two minutes or until 4096 velocity measurements were made in either the U or the V components. During this time conditional sampling techniques were employed to determine the location of the four blades and to permanently associate each measured velocity with the location of the blade when the measurement was made. At the conclusion of that process the measurement location was changed and the acquisition process was repeated.

DATA REDUCTION

Independent velocity measurements in the free stream and vertical direction were made at each measurement location. At the same instant in time that a velocity measurement was made, the location of the blades was recorded for that velocity

component. The maximum time required to acquire this data was two minutes (4200 rotor revolutions for this test) and the minimum approximately 20 sec. These data were collected over many spaced azimuth segments that are representative of blade position and include the corrections for blade lead/lag motion. The velocity value assigned to each azimuthal interval is the arithmetic mean of all of the measurements that were taken in the respective 2.81° wide azimuth range. The results of this sorting process provide the azimuth dependent velocity data. The "mean" velocity value refers to the arithmetic mean, calculated from all of the measurements made at a single measurement location.

EXPERIMENTAL RESULTS

Table 3 lists the measurement locations, the mean and standard deviation of the 2 components of induced inflow velocity, and the number of measurements made on the U and V components. In figure 9 the mean induced component of velocity (longitudinal) μ_i with a band of ± one standard deviation is plotted vs. radius for each radial scan. Figure 10 presents in the same format the mean induced component of velocity (normal) λ_i. The ± one standard deviation is not indicative of the error but rather of the unsteady nature of the flow. The error of 1.76 percent ±0.38 percent is approximately equal to the size of the symbols in figures 9 and 10. The same data, without the one standard deviation, is presented in a contour plot format in figures 11 and 12 in order to more clearly show the mean induced flow over the whole disk (viewed from above). The format of each of figures 13 through 192 is the induced velocity vs. azimuth at the top of the figure, the number of measurements that went into determining the mean for each bin in the center, and an order ratio analysis of the time dependent data at the bottom of the figure. The figure numbers for the azimuthal and radial locations are indicated below.

Azimuth / r/R	0	30	60	90	120	150	180	210	240	270	300	330
0.20	13	28	43	58	73	88	103	118	133	148	163	178
0.40	14	29	44	59	74	89	104	119	134	149	164	179
0.50	15	30	45	60	75	90	105	120	135	150	165	180
0.60	16	31	46	61	76	91	106	121	136	151	166	181
0.70	17	32	47	62	77	92	107	122	137	152	167	182
0.74	18	33	48	63	78	93	108	123	138	153	168	183
0.78	19	34	49	64	79	94	109	124	139	154	169	184
0.82	20	35	50	65	80	95	110	125	140	155	170	185
0.86	21	36	51	66	81	96	111	126	141	156	171	186
0.90	22	37	52	67	82	97	112	127	142	157	172	187
0.94	23	38	53	68	83	98	113	128	143	158	173	188
0.98	24	39	54	69	84	99	114	129	144	159	174	189
1.02	25	40	55	70	85	100	115	130	145	160	175	190
1.04	26	40	56	71	86	101	116	131	146	161	176	191
1.10	27	42	57	72	87	102	117	132	147	162	177	192

The results shown in table 3, the mean and standard deviation of the induced inflow velocities, and the results shown in figures 13 through 192, the azimuth dependent induced inflow velocities, are included on a 5.25 in. floppy disk in Microsoft Corporation MS-DOS format (see pocket inside rear cover). The details of the data format, and file structure is located in the file "README.DOC". The disk is double sided with a density of 360 kbytes.

CONCLUDING REMARKS

The Laser Velocimeter provides a effective system for making measurements in the dynamic environment associated with rotorcraft. It has in fact been used on numerous occasions to measure the localized phenomena encountered in such flows. This investigation demonstrates the use of a mature system in mapping the flow into a representative rotor in forward flight. These measurements provide not only the mean values but azimuth dependent values as well, and they provide a detailed look at the nature of this flow.

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TABLE 1.- 2MRTS ROTOR AND BLADE CHARACTERSTICS

Hub Type	Fully Articulated
Number of blades	4
Airfoil section	NACA 0012
Hinge offset, in, r/R	2.00, .06
Root cutout, in, r/R	8.25, .24
Pitch-flap coupling angle, deg	0.0
Twist linear, deg	-8.0
Radius, R, in	33.88
Airfoil chord, C, in	2.6
Rotor solidity, $bc/\pi R$	0.0977
Blade Stiffness	
Flapwise lb-in^2	11500
Torsional lb-in^2	25500
Blade Weight, grams	259.3
Lead/lag damping in-lb/deg/sec	182.4

TABLE 2.- NOMINAL ROTOR CONTROLS AND PERFORMANCE PARAMETERS

C_D	0.0002
α, deg	-4.04
A_0, deg	10.31
A_1, deg	-1.55
B_1, deg	5.88
Coning, deg	2.13
μ_∞	0.301
C_T	0.00649
C_Q	0.00043
V_∞, knots	111.357
V_{tip}, ft/sec	622.70
M_{tip}, nondimensional	0.5364
Lag angle, (mean), deg	0.90

TABLE 3.- INFLOW VELOCITY SUMMARY

		μ_1			λ_1		
ψ	r/R	Mean	Standard deviation	# measurements	Mean	Standard deviation	# measurements
0	.20	.0265	.0126	2215	.0092	.0116	1110
0	.40	.0198	.0110	2965	-.0049	.0126	1788
0	.50	.0198	.0101	1962	-.0051	.0061	1190
0	.60	.0173	.0097	1799	-.0073	.0066	766
0	.70	.0181	.0090	3018	-.0144	.0105	1561
0	.74	.0158	.0090	3052	-.0189	.0098	1932
0	.78	.0162	.0090	3014	-.0189	.0090	1881
0	.82	.0154	.0092	2885	-.0207	.0090	1897
0	.86	.0148	.0091	2714	-.0238	.0112	2064
0	.90	.0146	.0090	2611	-.0230	.0095	2013
0	.94	.0138	.0090	2620	-.0230	.0084	1802
0	.98	.0122	.0091	2624	-.0234	.0083	1670
0	1.02	.0113	.0094	2349	-.0259	.0095	1944
0	1.04	.0099	.0093	2129	-.0259	.0094	1817
0	1.10	.0082	.0092	2181	-.0264	.0081	1664
30	.20	.0148	.0098	1776	-.0258	.0063	421
30	.40	.0145	.0096	1728	-.0104	.0089	2261
30	.50	.0133	.0092	1646	-.0157	.0097	2180
30	.60	.0139	.0084	1676	-.0202	.0085	2329
30	.70	.0127	.0074	1538	-.0249	.0088	2672
30	.74	.0127	.0069	1250	-.0259	.0086	2656
30	.78	.0108	.0067	1127	-.0277	.0087	2736
30	.82	.0107	.0064	1096	-.0280	.0087	2461
30	.86	.0096	.0061	897	-.0281	.0074	2288
30	.90	.0092	.0075	3450	-.0257	.0074	2419
30	.94	.0077	.0074	3496	-.0258	.0069	2237
30	.98	.0068	.0078	3335	-.0246	.0071	2343
30	1.02	.0068	.0077	3407	-.0232	.0077	2452
30	1.04	.0060	.0078	2813	-.0232	.0080	2272
30	1.10	.0053	.0079	2206	-.0218	.0080	2266
60	.20	.0130	.0086	1432	-.0225	.0056	343
60	.40	.0141	.0078	994	-.0026	.0078	1905
60	.50	.0148	.0056	918	-.0182	.0077	2643
60	.60	.0128	.0052	691	-.0176	.0081	2297
60	.70	.0104	.0047	712	-.0139	.0076	2854
60	.74	.0144	.0071	2875	-.0130	.0079	2452
60	.78	.0144	.0084	2908	-.0106	.0069	2142
60	.82	.0121	0079	3064	-.0083	.0071	2291
60	.86	.0116	.0078	3119	-.0076	.0070	2277
60	.90	.0113	.0079	3469	-.0062	.0071	2542
60	.94	.0086	.0078	3306	-.0030	.0061	2333
60	.98	.0085	.0078	3356	-.0005	.0057	2340
60	1.02	.0075	.0076	3323	.0028	.0047	2236
60	1.04	.0065	.0077	3194	-.0047	.0044	2222
60	1.10	.0053	.0074	2986	-.0102	.0039	2161

TABLE 3.- Continued

		μ_1			λ_1		
ψ	r/R	Mean	Standard deviation	# measurements	Mean	Standard deviation	# measurements
90	.20	.0112	.0079	2898	.0040	.0059	2080
90	.40	.0136	.0071	3003	-.0056	.0063	1569
90	.50	.0126	.0072	3214	-.0019	.0074	1945
90	.60	.0108	.0075	3208	.0025	.0069	2047
90	.70	.0091	.0076	2076	.0057	.0073	1478
90	.74	.0086	.0071	1762	.0062	.0048	1059
90	.78	.0081	.0070	1719	.0083	.0049	1127
90	.82	.0067	.0070	2184	.0098	.0049	1313
90	.86	.0057	.0069	3451	.0104	.0048	2219
90	.90	.0050	.0068	3493	.0113	.0048	2335
90	.94	.0040	.0065	3518	.0123	.0058	2548
90	.98	.0038	.0062	3380	.0121	.0050	2459
90	1.02	.0041	.0061	3274	.0125	.0060	2685
90	1.04	.0033	.0061	3274	.0108	.0054	2610
90	1.10	.0026	.0057	1647	.0104	.0047	1291
120	.20	.0929	.0071	2981	.0038	.0070	2133
120	.40	.0111	.0073	3277	.0019	.0072	1955
120	.50	.0119	.0070	3343	.0027	.0074	1866
120	.60	.0099	.0071	3305	.0073	.0054	1883
120	.70	.0056	.0071	3099	.0096	.0058	1949
120	.74	.0055	.0070	2898	.0081	.0048	1629
120	.78	.0049	.0067	2454	.0103	.0059	1627
120	.82	.0044	.0069	2043	.0093	.0056	1324
120	.86	.0034	.0068	1997	.0099	.0055	1229
120	.90	.0023	.0062	1942	.0097	.0056	1250
120	.94	.0013	.0062	2115	.0098	.0056	1352
120	.98	.0002	.2249	0082	.0082	.0050	1350
120	1.02	.0006	.0061	1530	.0082	.0048	996
120	1.04	.0008	.0060	3469	.0067	.0050	1394
120	1.10	0.0000	.0056	3485	.0068	.0048	1339
150	.20	.0064	.0064	2881	.0079	.0059	1684
150	.40	.0091	.0068	3043	.0068	.0061	1394
150	.50	.0086	.0072	2912	.0075	.0059	1375
150	.60	.0080	.0070	3081	.0084	.0076	1720
150	.70	.0058	.0065	2418	.0103	.0066	1355
150	.74	.0052	.0062	2136	.0107	.0066	1211
150	.78	.0047	.0061	2311	.0117	.0080	1211
150	.82	.0046	.0060	2211	.0118	.0068	1345
150	.86	.0045	.0060	2461	.0105	.0077	1517
150	.90	.0018	.0060	2734	.0108	.0061	1448
150	.94	.0004	.0059	2769	.0100	.0057	1425
150	.98	-.0002	.0058	2753	.0085	.0049	1211
150	1.02	-.0002	.0055	2650	.0092	.0068	1523
150	1.04	.0003	.0054	2580	.0091	.0071	1644
150	1.10	-.0010	.0056	3034	.0062	.0056	973

TABLE 3.- Continued

ψ	r/R	μ_1 Mean	μ_1 Standard deviation	μ_1 # measurements	λ_1 Mean	λ_1 Standard deviation	λ_1 # measurements
180	.20	.0012	.0067	3624	.0103	.0064	2339
180	.40	.0096	.0056	3639	.0044	.0082	2692
180	.50	.0116	.0065	3526	.0058	.0076	2850
180	.60	.0107	.0072	2960	.0071	.0095	2760
180	.70	.0104	.0066	3630	.0085	.0114	2620
180	.78	.0062	.0076	3474	.0098	.0100	2561
180	.82	.0052	.0082	3183	.0103	.0095	2705
180	.86	.0054	.0082	3087	.0104	.0090	2640
180	.90	.0031	.0083	3207	.0107	.0080	2670
180	.94	.0017	.0078	3205	.0110	.0064	2617
180	.98	.0006	.0074	3039	.0108	.0057	2613
180	1.02	-.0015	.0068	3088	.0102	.0052	2491
180	1.04	-.0012	.0067	3090	.0090	.0062	2588
180	1.10	-.0010	.0064	3038	.0079	.0052	2416
210	.20	.0040	.0069	3455	.0089	.0065	2036
210	.40	.0088	.0069	3344	.0023	.0070	2230
210	.50	.0113	.0079	3446	.0029	.0086	2309
210	.60	.0126	.0096	3547	.0015	.0018	2421
210	.70	.0118	.0103	3195	.0020	.0137	2630
210	.74	.0120	.0106	3279	.0039	.0126	2354
210	.78	.0116	.0105	3390	.0064	.0103	2212
210	.82	.0109	.0109	3436	.0060	.0109	2323
210	.86	.0104	.0109	3335	.0083	.0072	2150
210	.90	.0084	.0108	3186	.0084	.0062	2233
210	.94	.0060	.0103	3032	.0083	.0059	2213
210	.98	.0028	.0092	2862	.0080	.0059	2312
210	1.02	.0040	.0081	2928	.0074	.0059	2315
210	1.04	.0036	.0083	2640	.0073	.0059	2386
210	1.10	.0014	.0077	2346	.0062	.0063	2466
240	.20	.0080	.0068	3427	.0067	.0061	1728
240	.40	.0112	.0081	3014	-.0008	.0066	2003
240	.50	.0124	.0091	2769	-.0017	.0094	2044
240	.60	.0134	.0113	2586	-.0001	.0096	1875
240	.70	.0125	.0123	2557	-.0008	.0177	2050
240	.74	.0126	.0123	2651	-.0004	.0126	2139
240	.78	.0120	.0123	3115	.0010	.0123	2292
240	.82	.0134	.0127	3424	.0047	.0093	1864
240	.86	.0123	.0120	3271	.0064	.0102	2251
240	.90	.0115	.0115	3263	.0093	.0094	2339
240	.94	.0102	.0107	3228	.0096	.0093	2538
240	.98	.0078	.0094	3191	.0092	.0068	2254
240	1.02	.0077	.0085	3124	.0096	.0077	2521
240	1.04	.0051	.0086	2836	.0093	.0078	2442
240	1.10	.0052	.0084	2947	.0087	.0081	2407

TABLE 3.- Concluded

		μ_1			λ_1		
ψ	r/R	Mean	Standard deviation	# measurements	Mean	Standard deviation	# measurements
270	.20	.0139	.0075	3309	.0071	.0063	1865
270	.40	.0120	.0085	3092	.0003	.0078	2222
270	.50	.0126	.0089	3134	-.0016	.0077	2249
270	.60	.0124	.0091	3087	-.0018	.0088	2265
270	.70	.0127	.0100	3251	-.0030	.0115	2274
270	.74	.0130	.0108	3265	-.0027	.0118	2004
270	.78	.0146	.0110	3283	-.0024	.0115	2115
270	.82	.0149	.0112	3271	-.0043	.0014	1974
270	.86	.0142	.0113	3197	0.0000	.0126	2047
270	.90	.0131	.0109	3123	.0039	.0134	2425
270	.94	.0124	.0101	2926	.0077	.0099	2468
270	.98	.0104	.0098	2782	.0104	.0084	2472
270	1.02	.0087	.0091	2609	.0122	.0070	2416
270	1.04	.0086	.0087	2774	.0122	.0074	2534
270	1.10	.0064	.0086	2780	.0115	.0070	2486
300	.20	.0177	.0088	3247	.0060	.0069	2306
300	.40	.0148	.0079	3150	.0011	.0066	2029
300	.50	.0159	.0082	3336	-.0016	.0072	2040
300	.60	.0153	.0085	3227	-.0047	.0063	1767
300	.70	.0145	.0092	3151	-.0070	.0069	2002
300	.74	.0133	.0095	2984	-.0081	.0075	2055
300	.78	.0144	.0097	3226	-.0097	.0084	2010
300	.82	.0139	.0096	2325	-.0105	.0083	1351
300	.86	.0145	.0097	2308	-.0134	.0100	1312
300	.90	.0138	.0096	2530	-.0145	.0088	1511
300	.94	.0115	.0093	2745	-.0153	.0102	1636
300	.98	.0107	.0094	2938	-.0158	.0103	1976
300	1.02	.0095	.0090	2698	-.0125	.0084	1677
300	1.04	.0097	.0093	2926	-.0099	.0082	2001
300	1.10	.0092	.0097	2546	.0014	.0070	2050
330	.20	.0225	.0096	2539	.0060	.0084	2429
330	.40	.0179	.0087	2796	.0001	.0071	2101
330	.50	.0159	.0089	2757	.0001	.0073	2076
330	.60	.0189	.0088	3109	-.0034	.0088	2044
330	.70	.0179	.0092	3111	-.0078	.0089	1857
330	.74	.0190	.0093	3162	-.0086	.0091	1793
330	.78	.0182	.0091	3171	-.0095	.0096	1780
330	.82	.0173	.0092	3175	-.0109	.0101	1822
330	.86	.0182	.0091	2987	-.0132	.0104	1678
330	.90	.0170	.0093	2686	-.0175	.0101	1366
330	.94	.0155	.0096	2718	-.0184	.0102	1437
330	.98	.0140	.0108	2968	-.0198	.0095	1487
330	1.02	.0127	.0118	2921	-.0207	.0096	1520
330	1.04	.0115	.0116	3201	-.0197	.0097	1744
330	1.10	.0101	.0119	3118	-.0176	.0109	2070

Figure 1.- Aerial view of 14- by 22-foot tunnel.

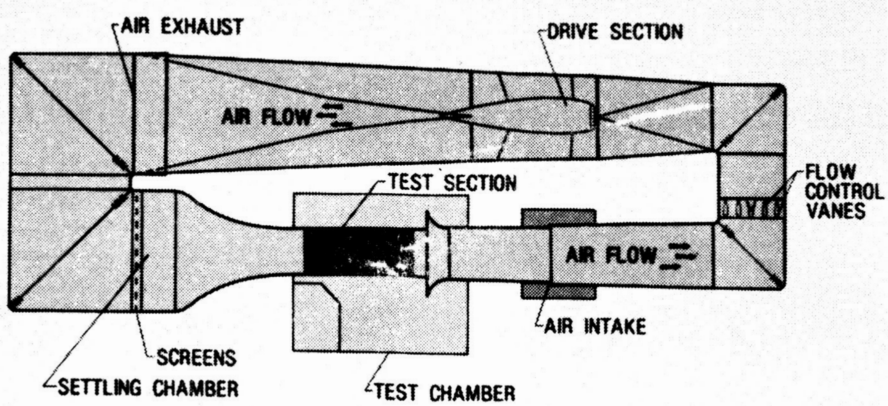

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Figure 2.- Schematic view of 14- by 22-foot
subsonic wind tunnel.

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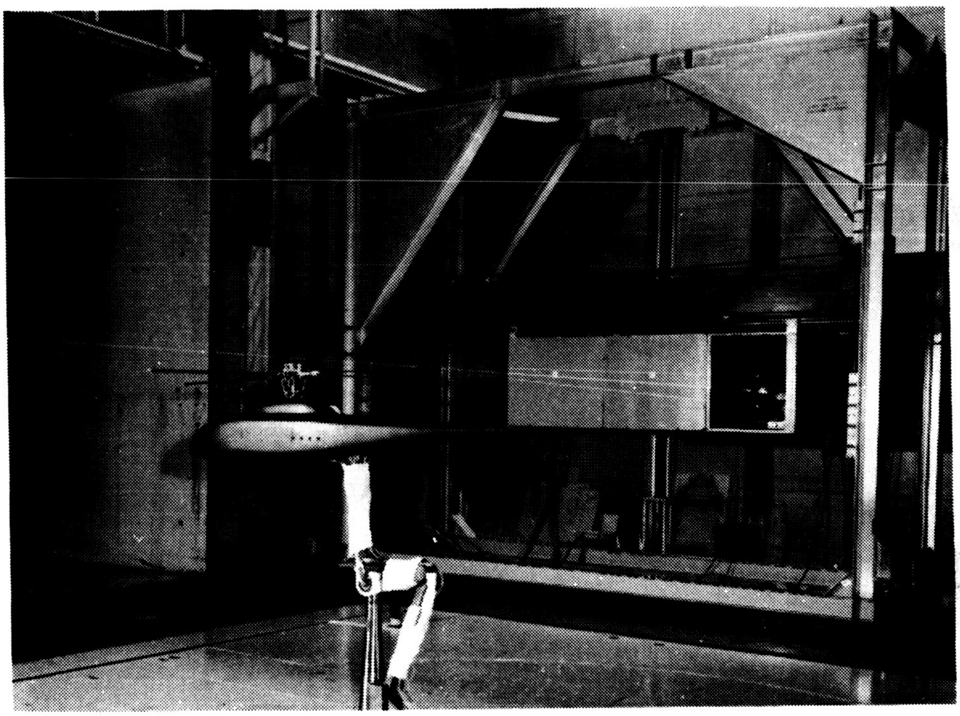

Figure 3.- 2MRTS mounted in forward bay
of the test section.

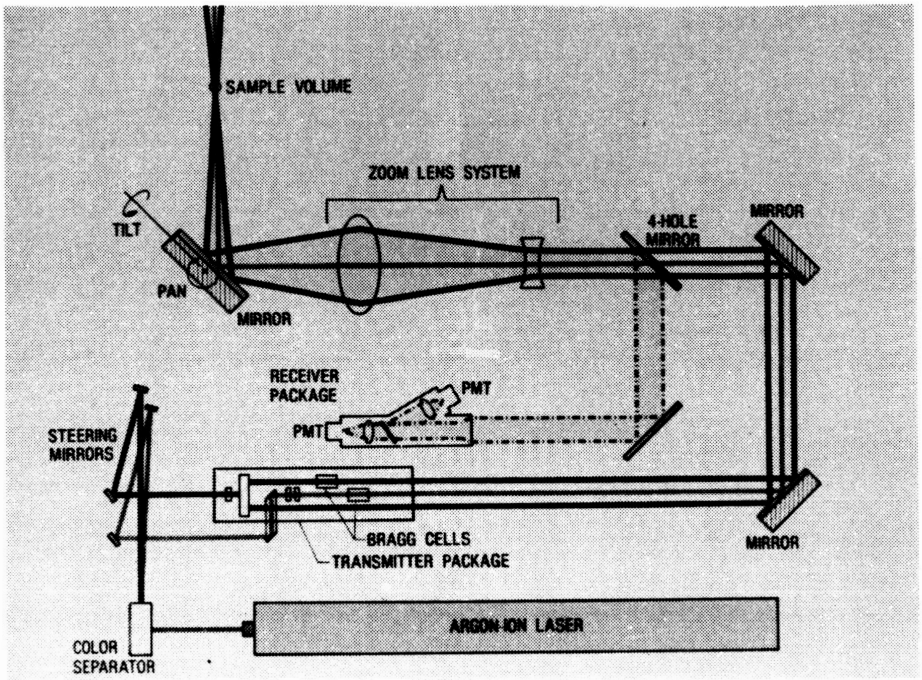

Figure 4.- Schematic diagram of Laser Velocimeter Optics Sub-system.

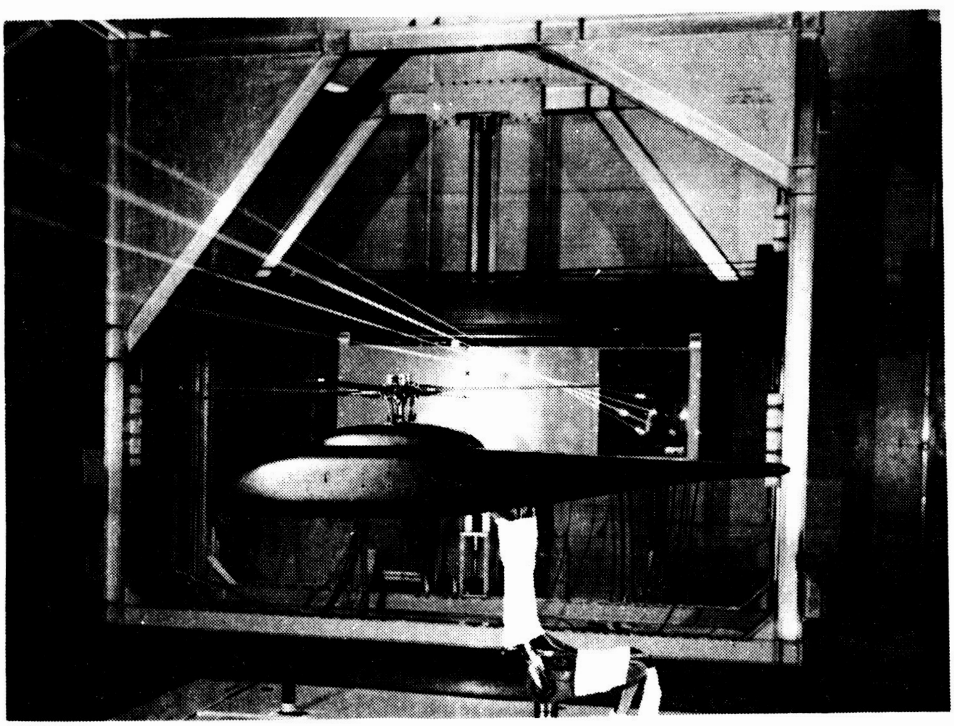

Figure 5.- Laser Velocimeter positioned in test chamber.

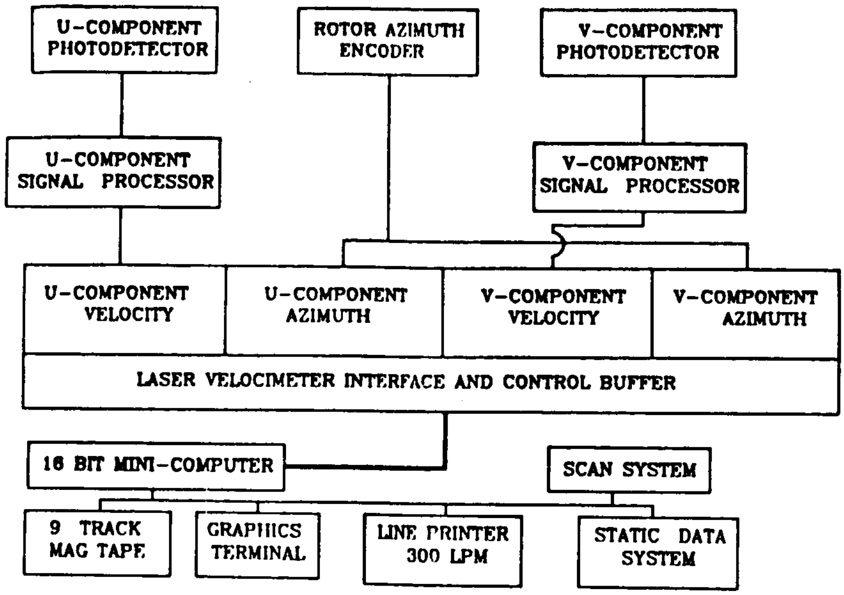

Figure 6.- Schematic view of data aquisition and control subsystem.

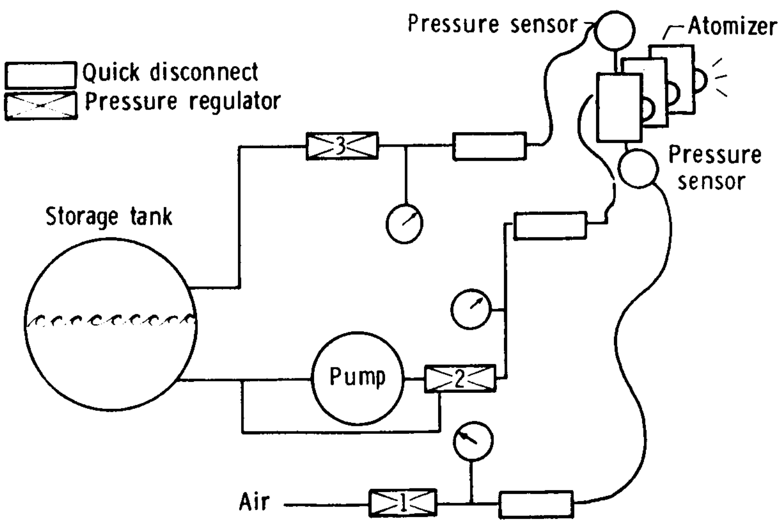

Figure 7.- Schematic of Seeding system.

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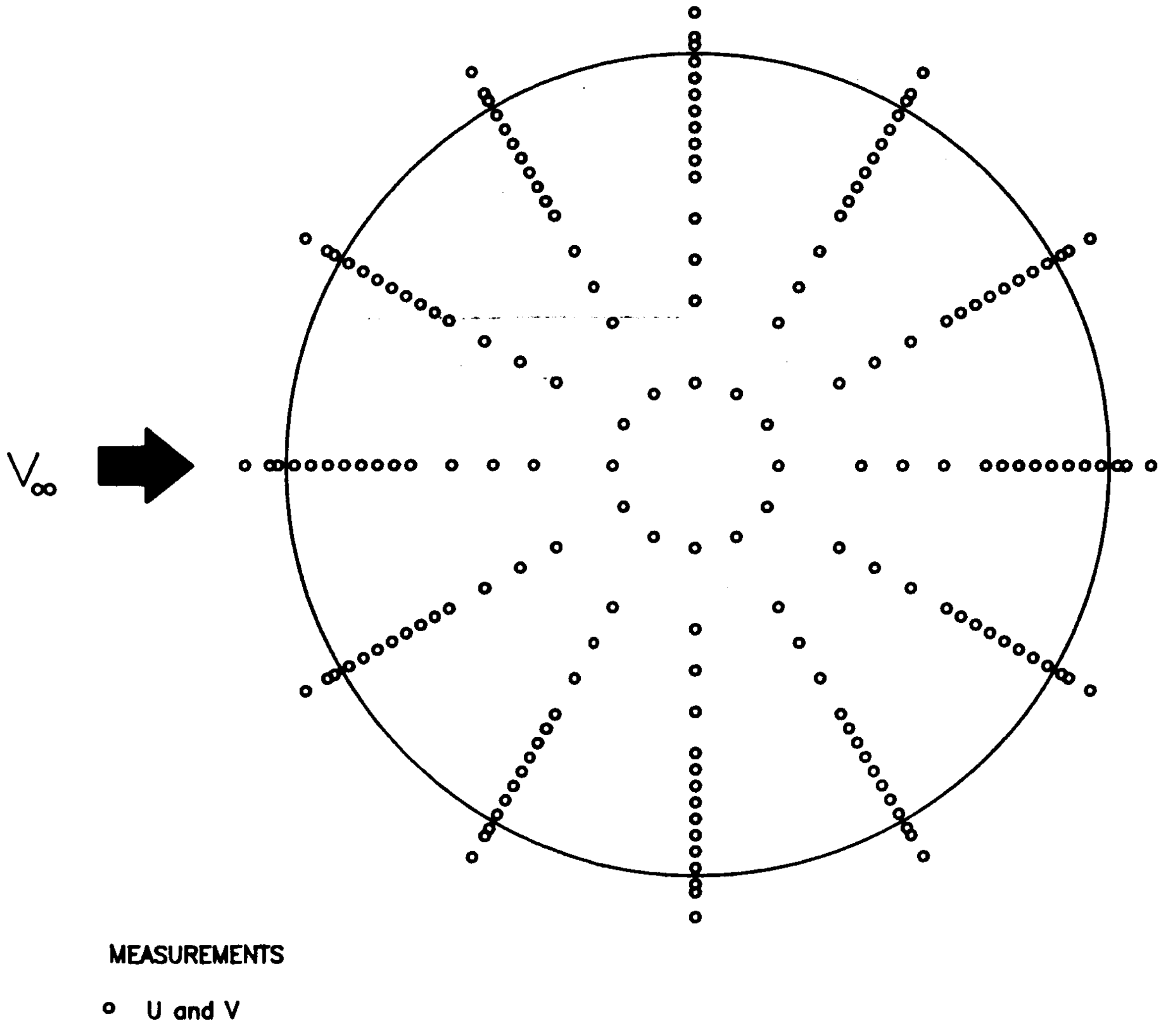

Figure 8.– Locations of velocity measurements, 3.0 inches above rotor tip path plane.

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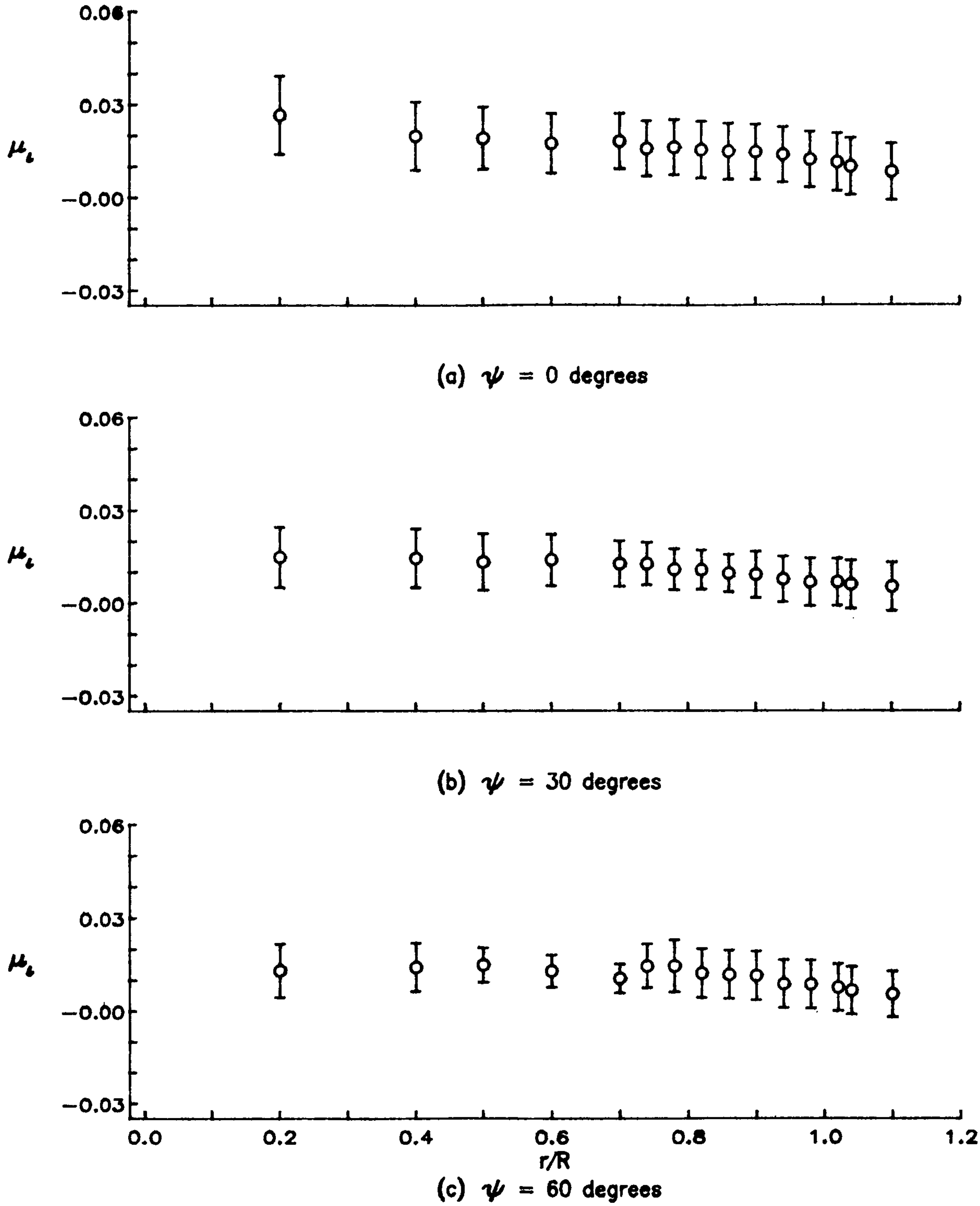
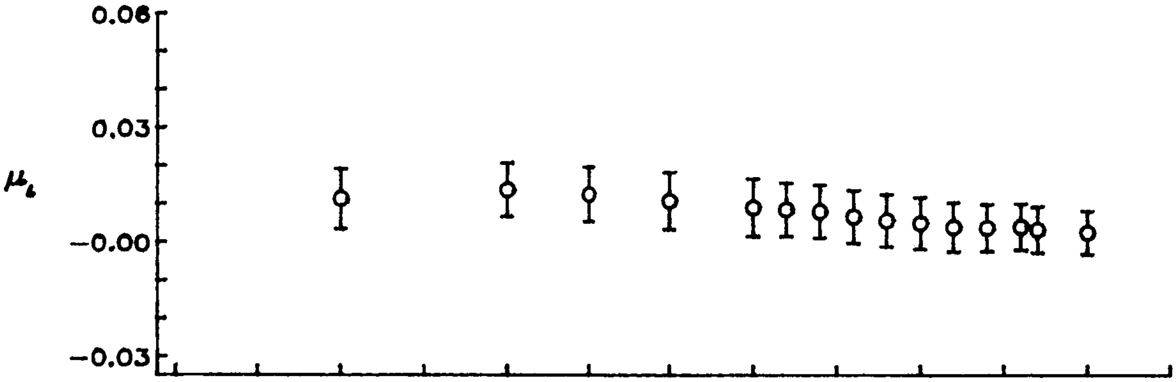
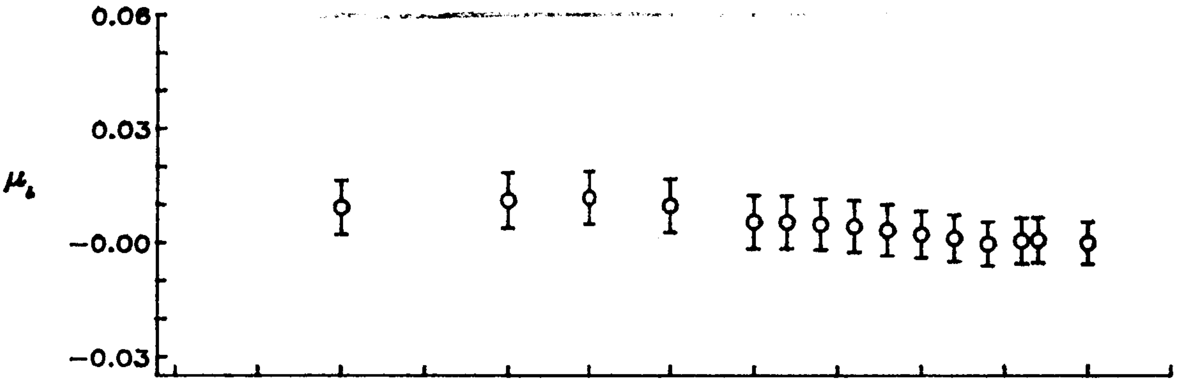


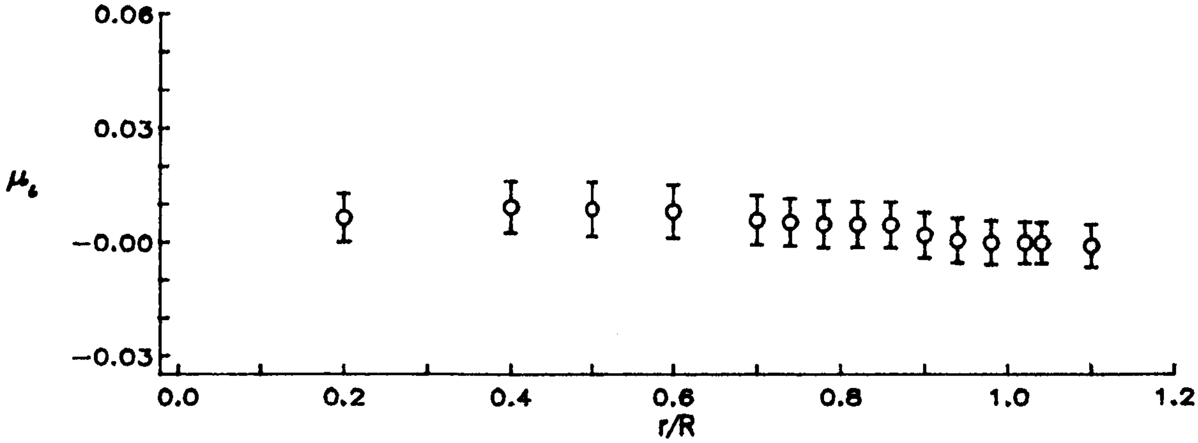
Figure 9.– Radial distribution of mean induced inflow ratio (μ_i).



(d) ψ = 90 degrees

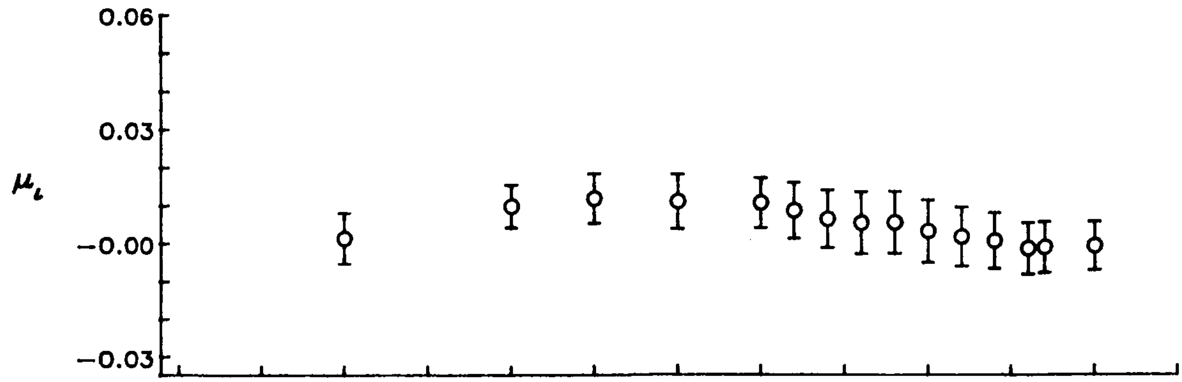


(e) ψ = 120 degrees

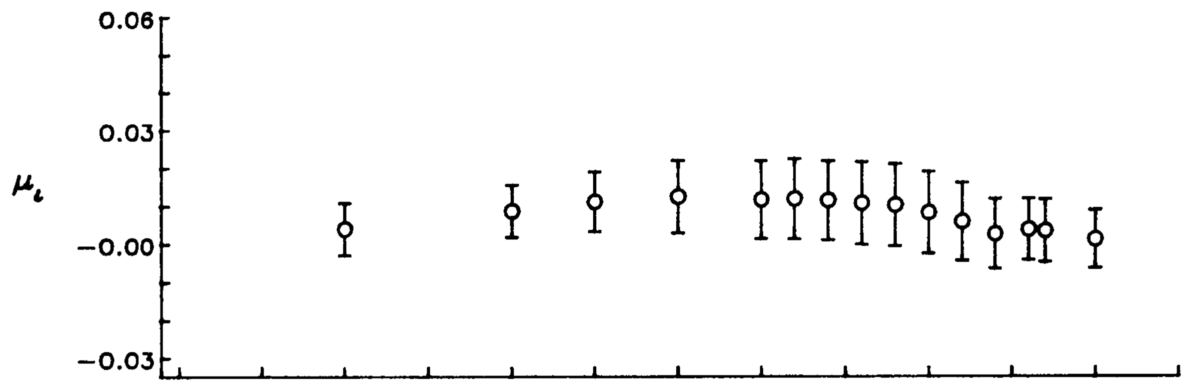


(f) ψ = 150 degrees

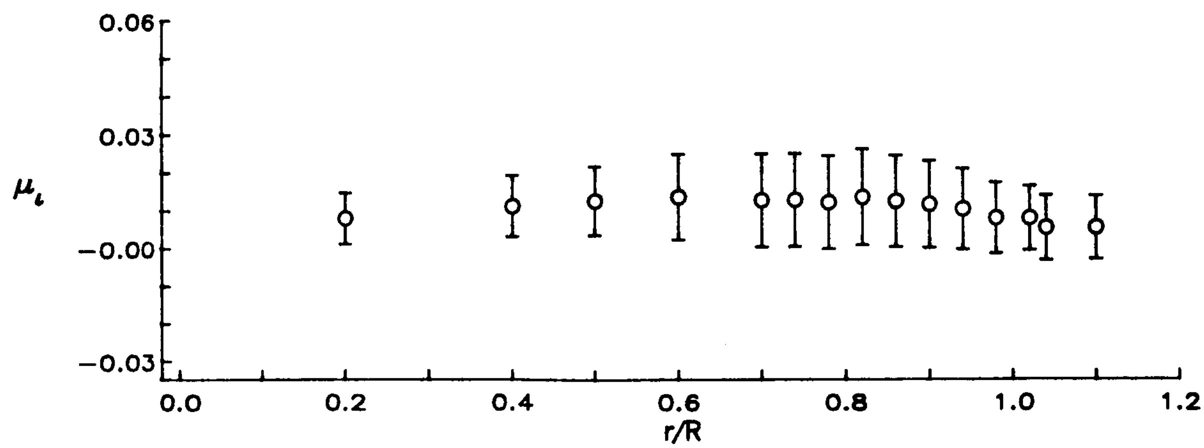
Figure 9.– Continued.



(g) ψ = 180 degrees

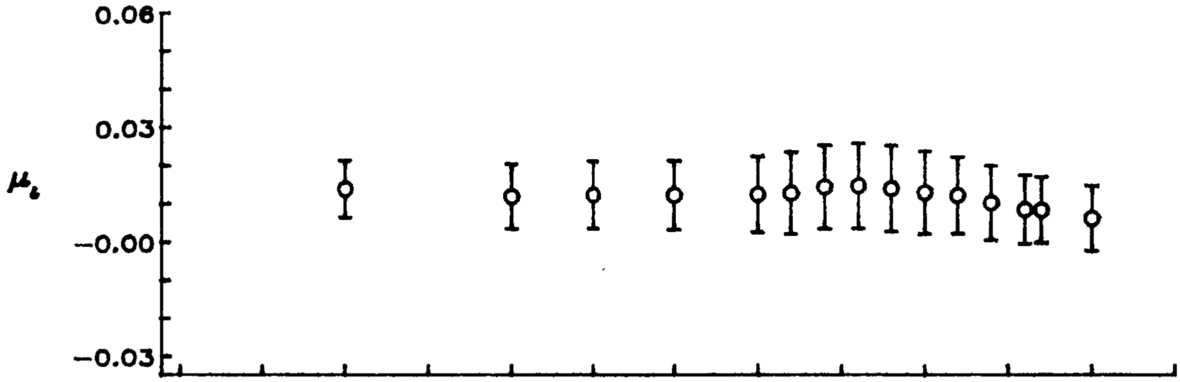


(h) ψ = 210 degrees

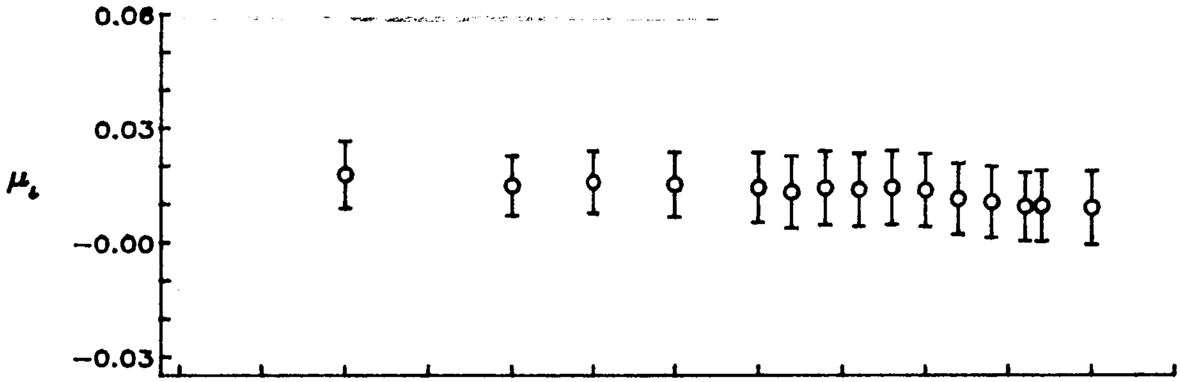


(i) ψ = 240 degrees

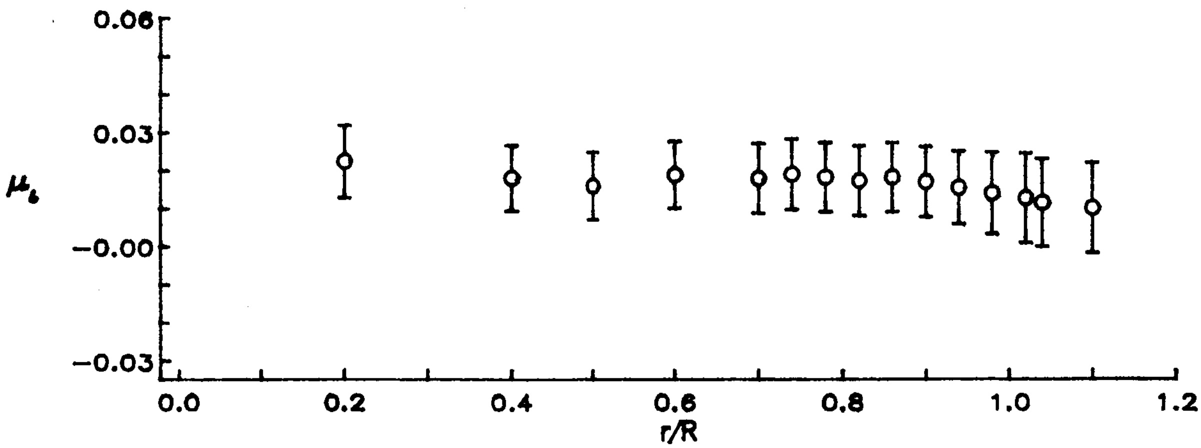
Figure 9.– Continued.



(j) ψ = 270 degrees

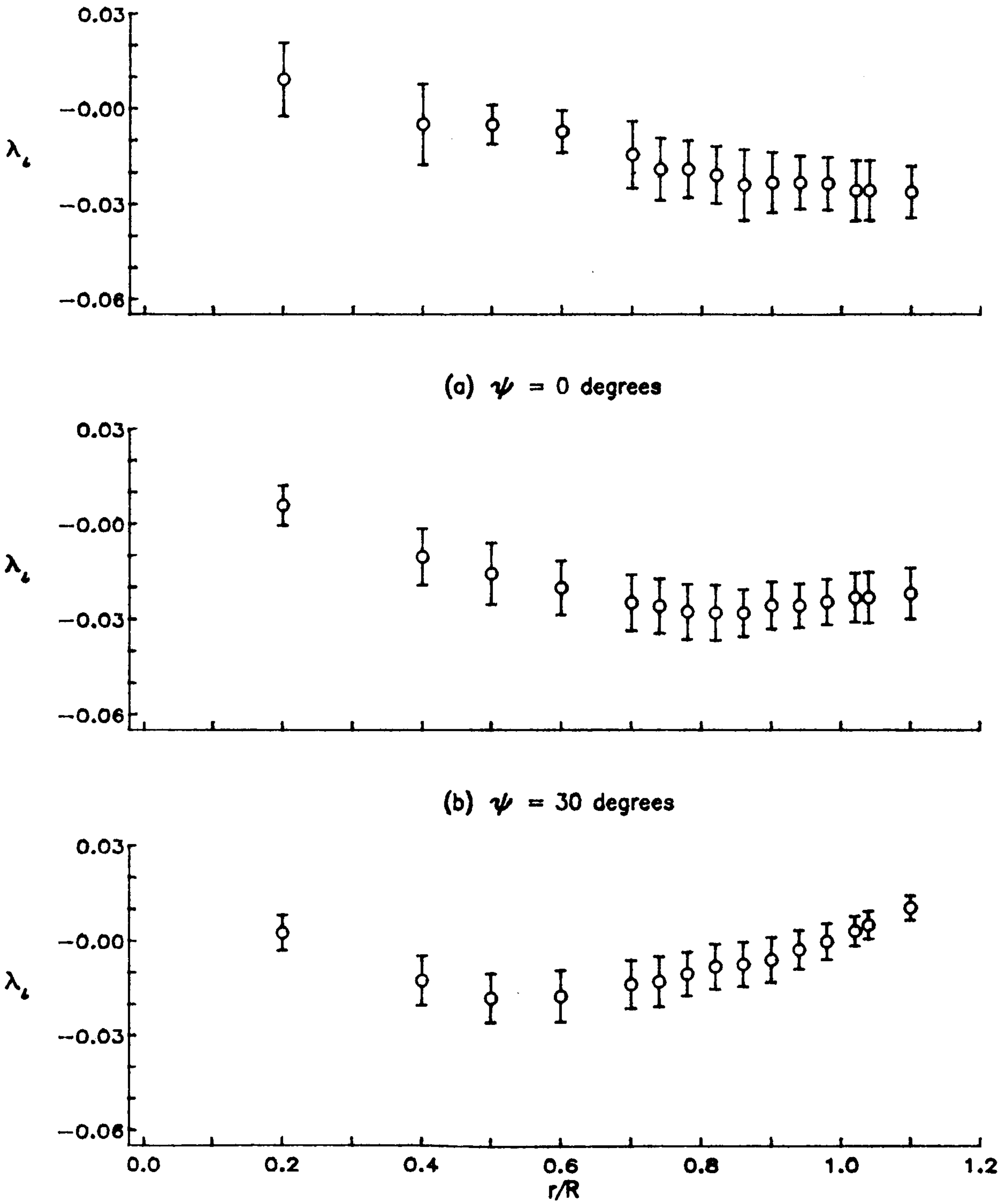


(k) ψ = 300 degrees



(l) ψ = 330 degrees

Figure 9.– Concluded.

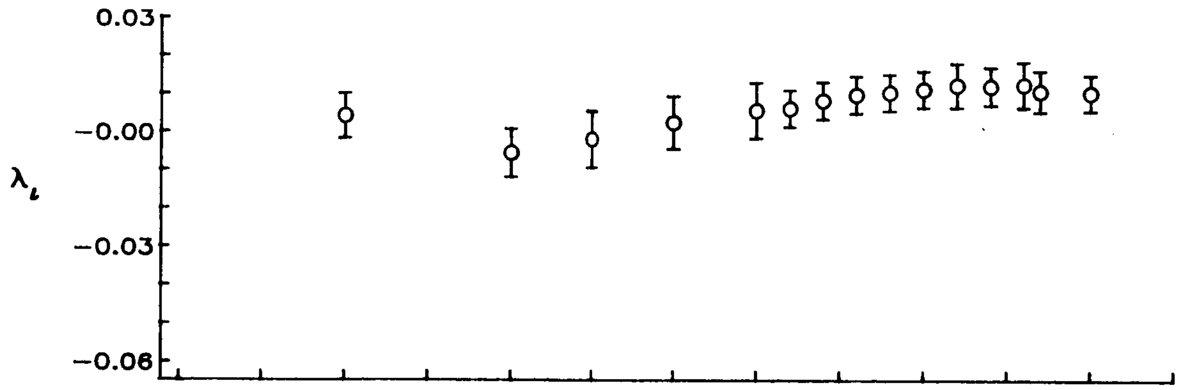


(a) ψ = 0 degrees

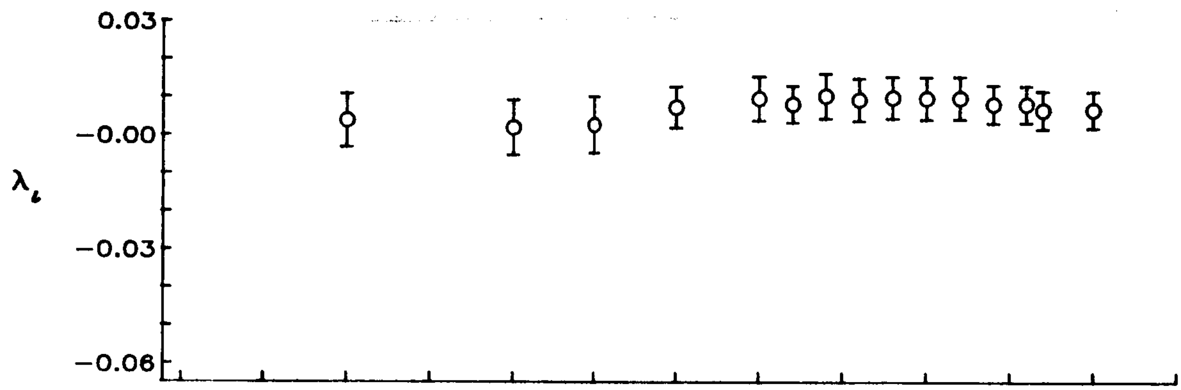
(b) ψ = 30 degrees

(c) ψ = 60 degrees

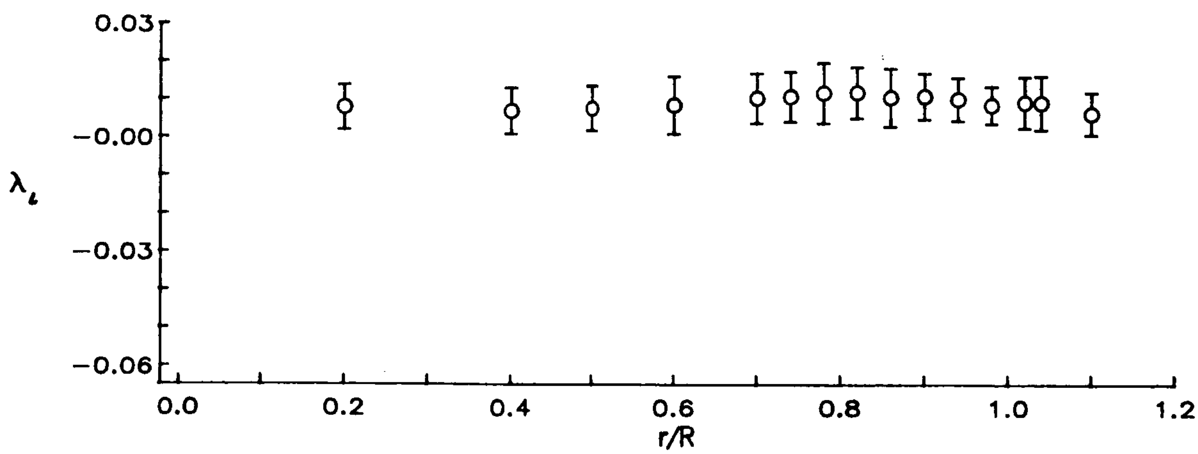
Figure 10.– Radial distribution of mean induced inflow ratio (λ_i).



(d) ψ = 90 degrees

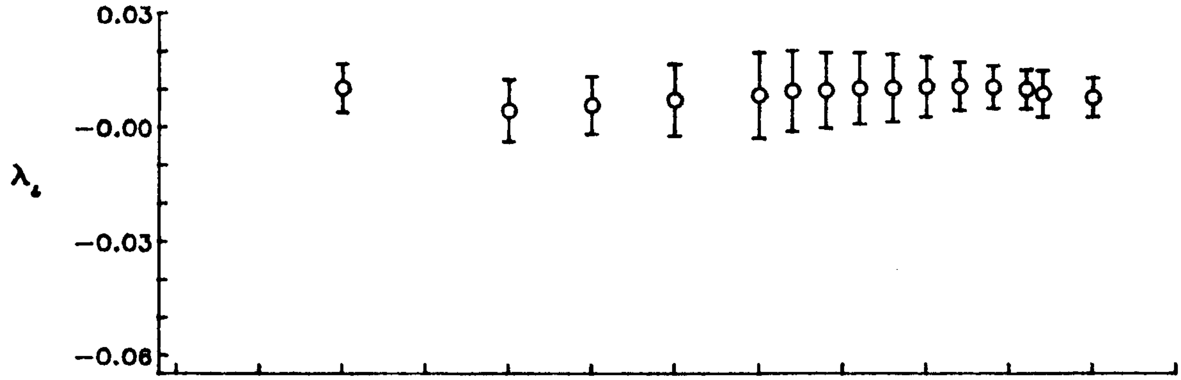


(e) ψ = 120 degrees

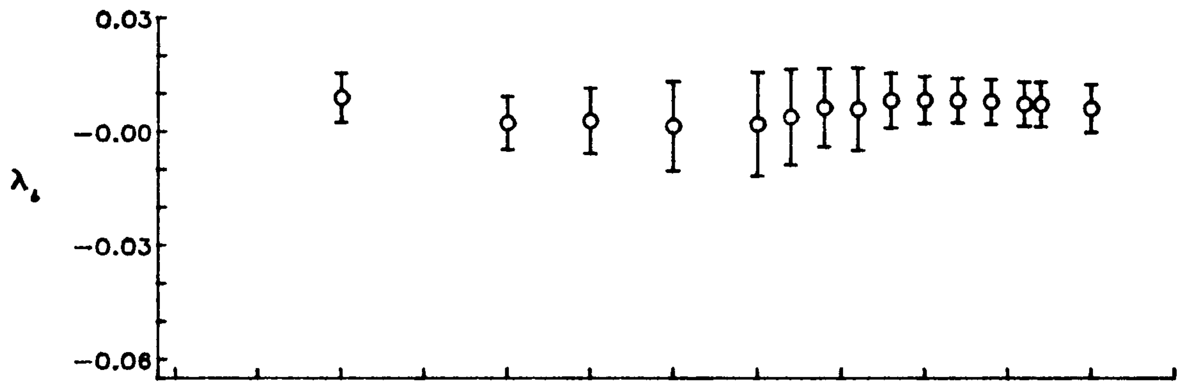


(f) ψ = 150 degrees

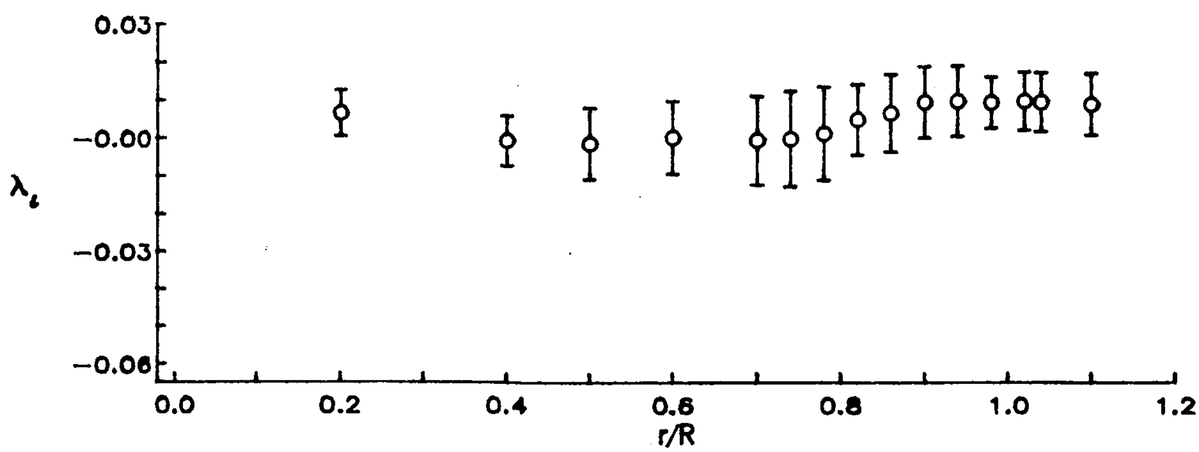
Figure 10.– Continued.



(g) ψ = 180 degrees

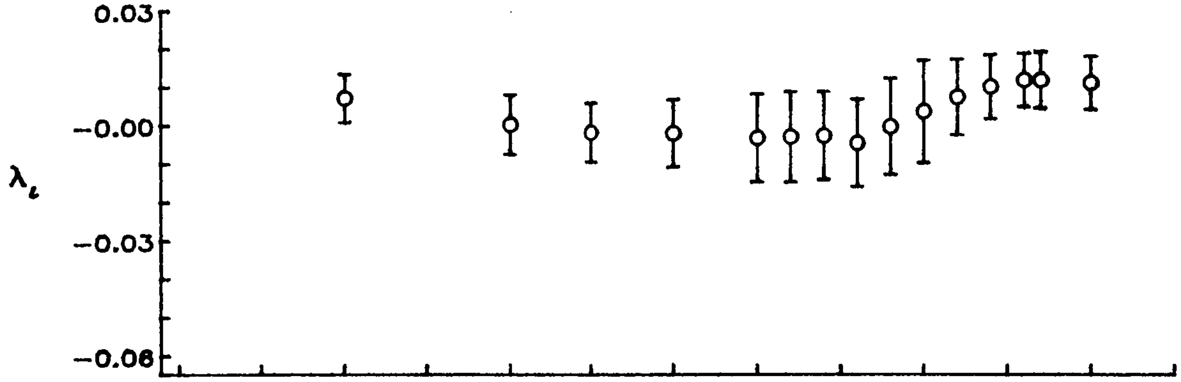


(h) ψ = 210 degrees

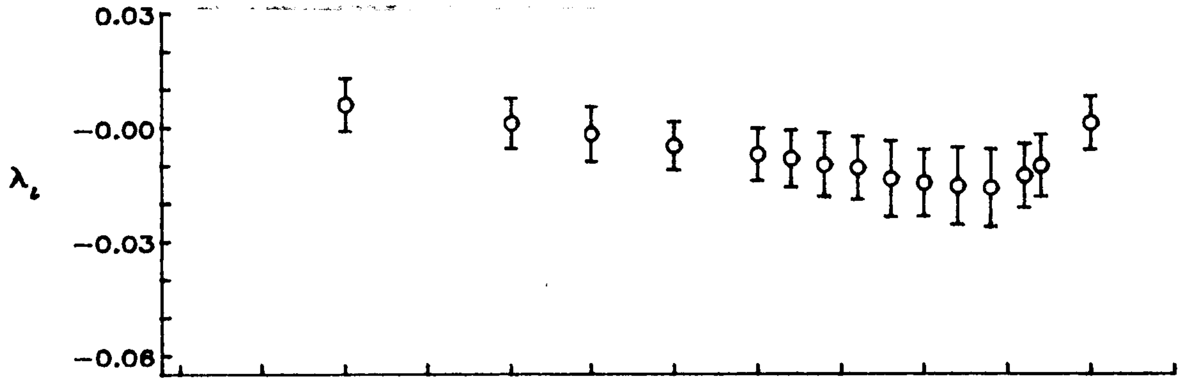


(i) ψ = 240 degrees

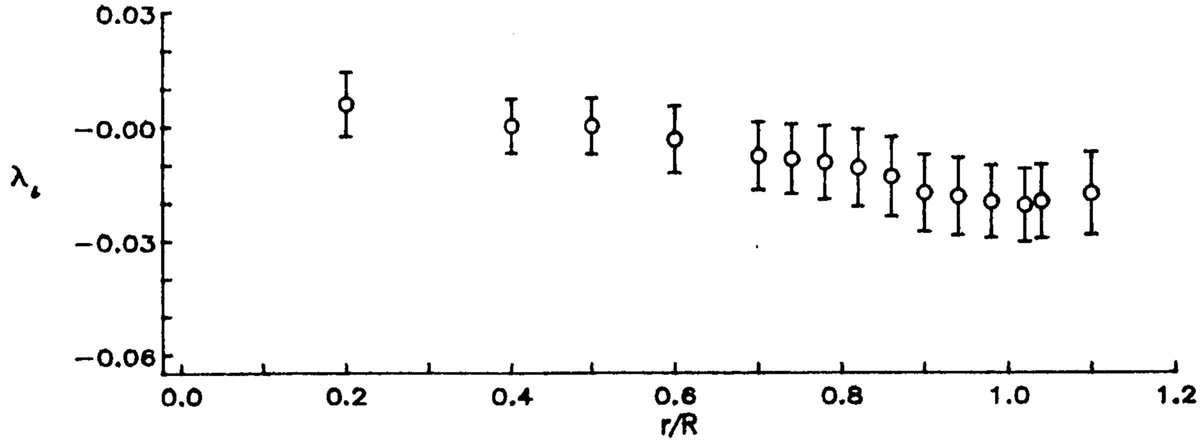
Figure 10.– Continued.



(j) ψ = 270 degrees



(k) ψ = 300 degrees



(l) ψ = 330 degrees

Figure 10.– Concluded.

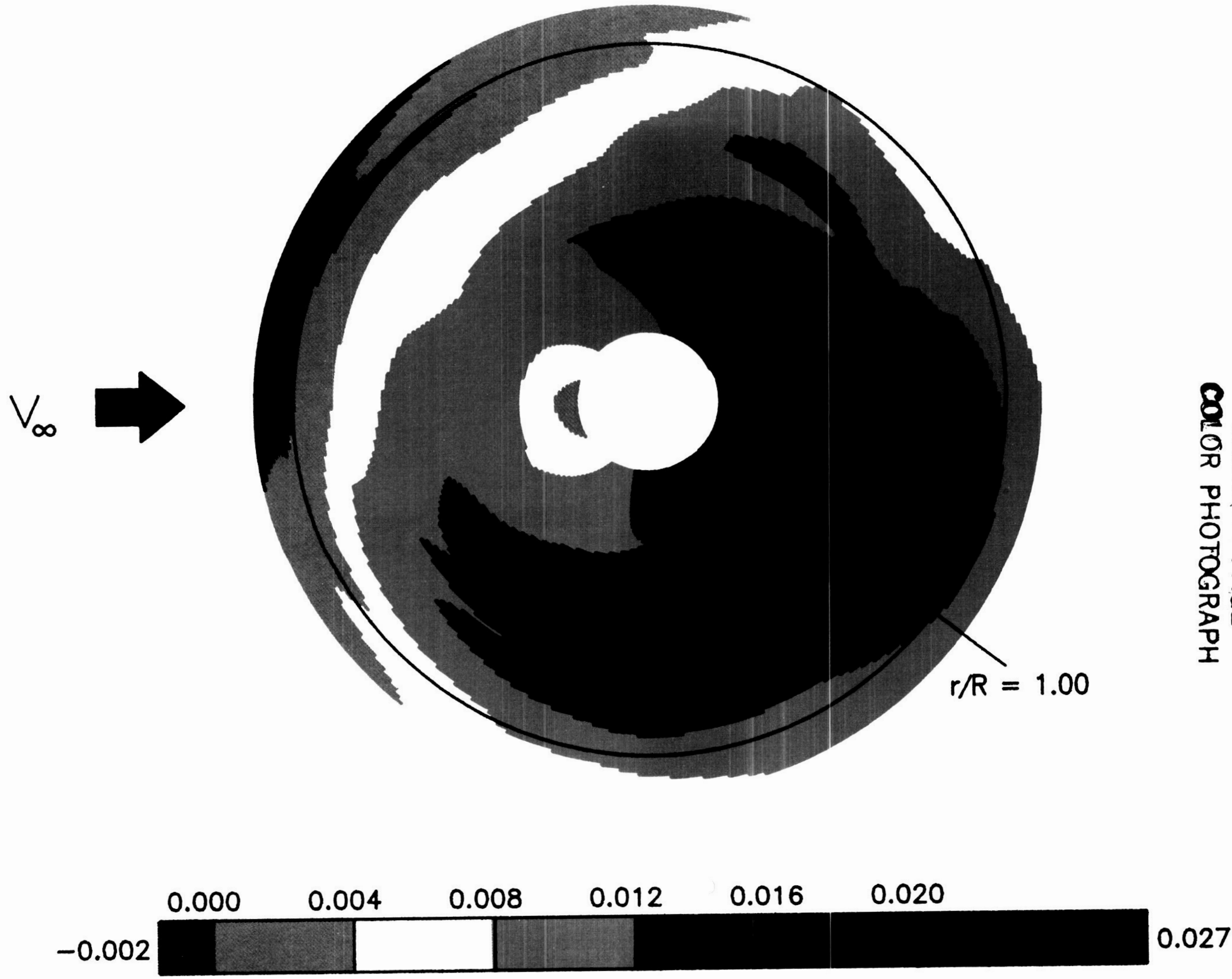


Figure 11.– Contour plot of mean induced inflow ratio (μ_i).

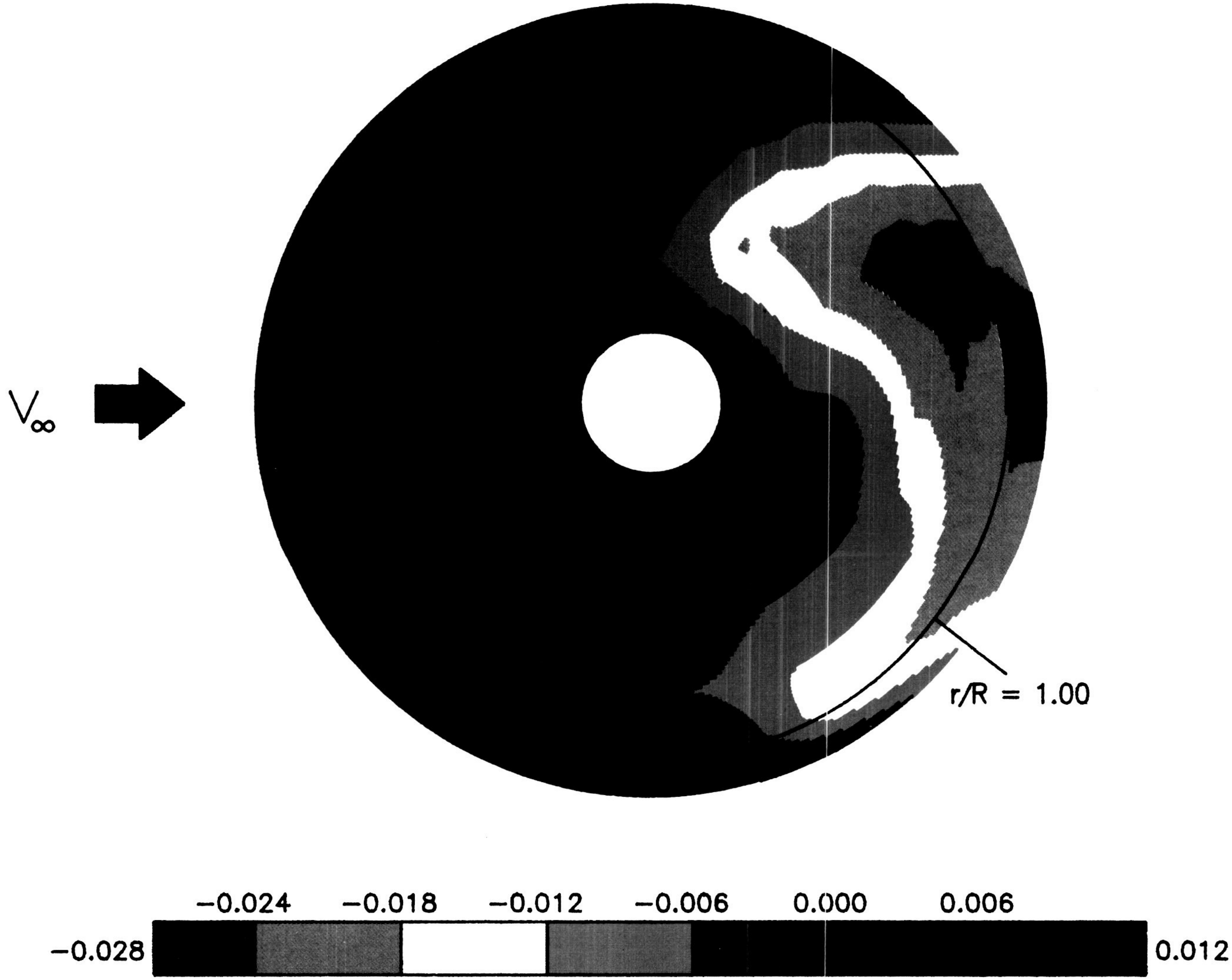


Figure 12.– Contour plot of mean induced inflow ratio (λ_i).

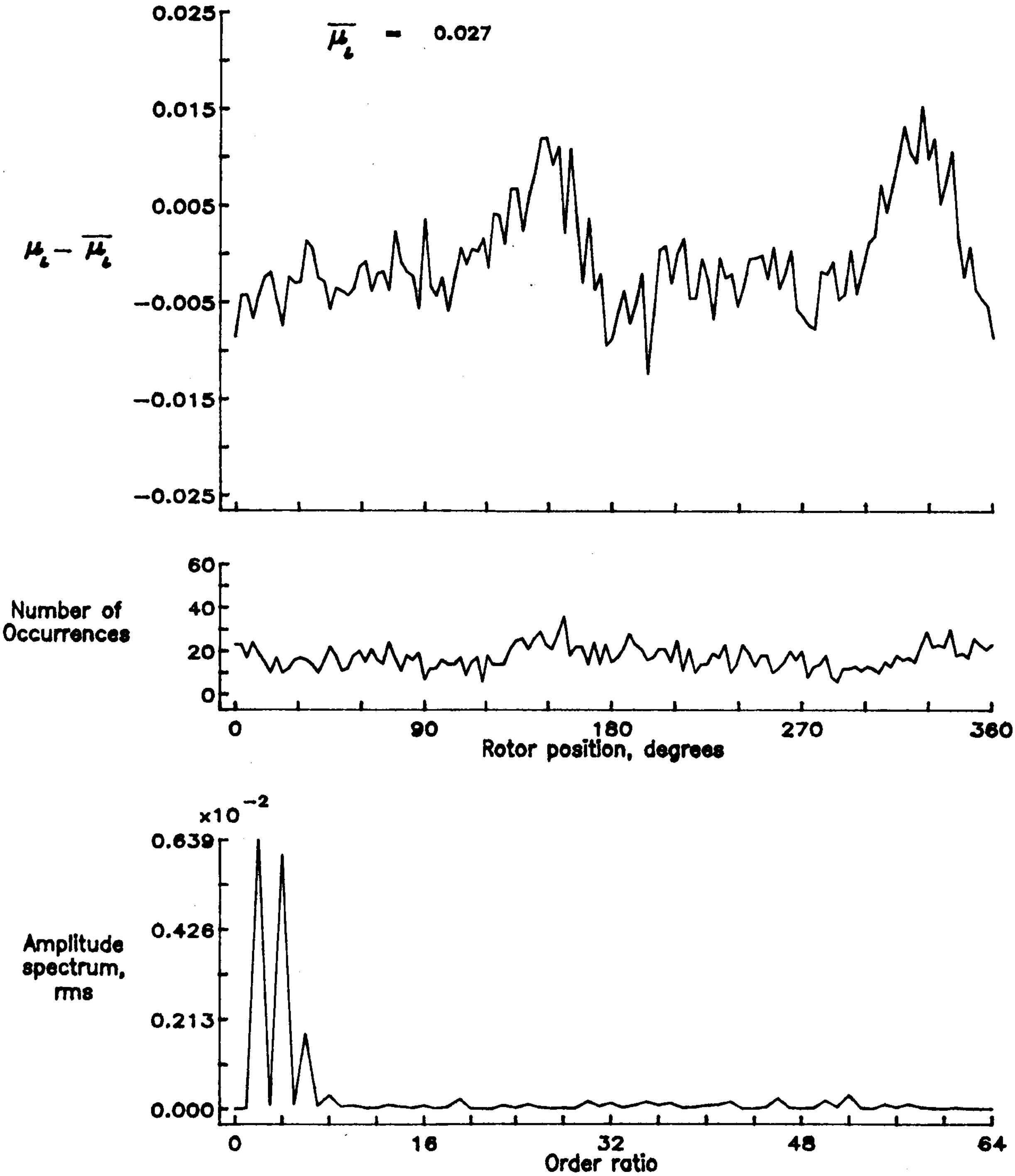


Figure 13.– Induced inflow velocity measured at 0 degrees and r/R of 0.20.

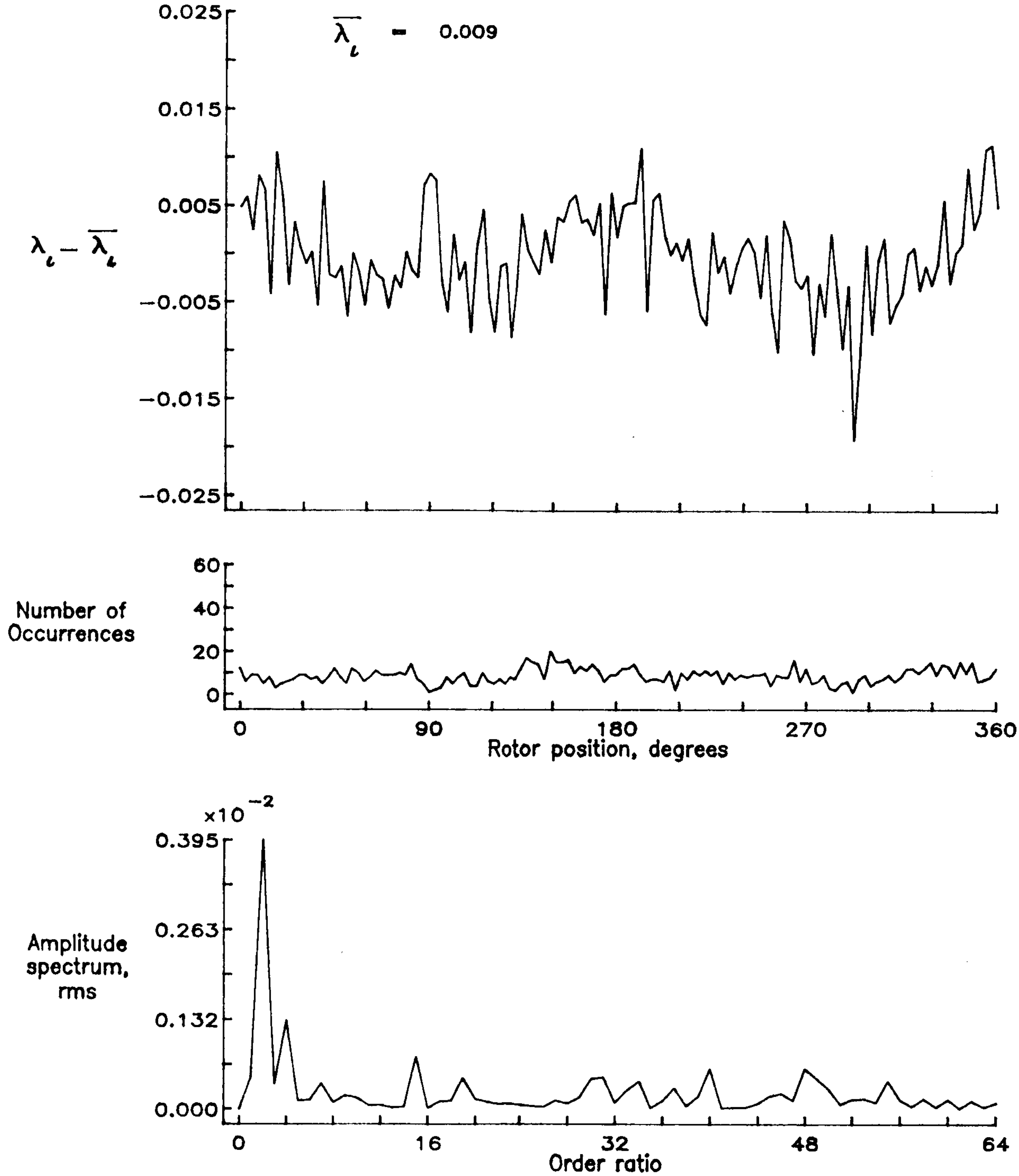


Figure 13.– Concluded.

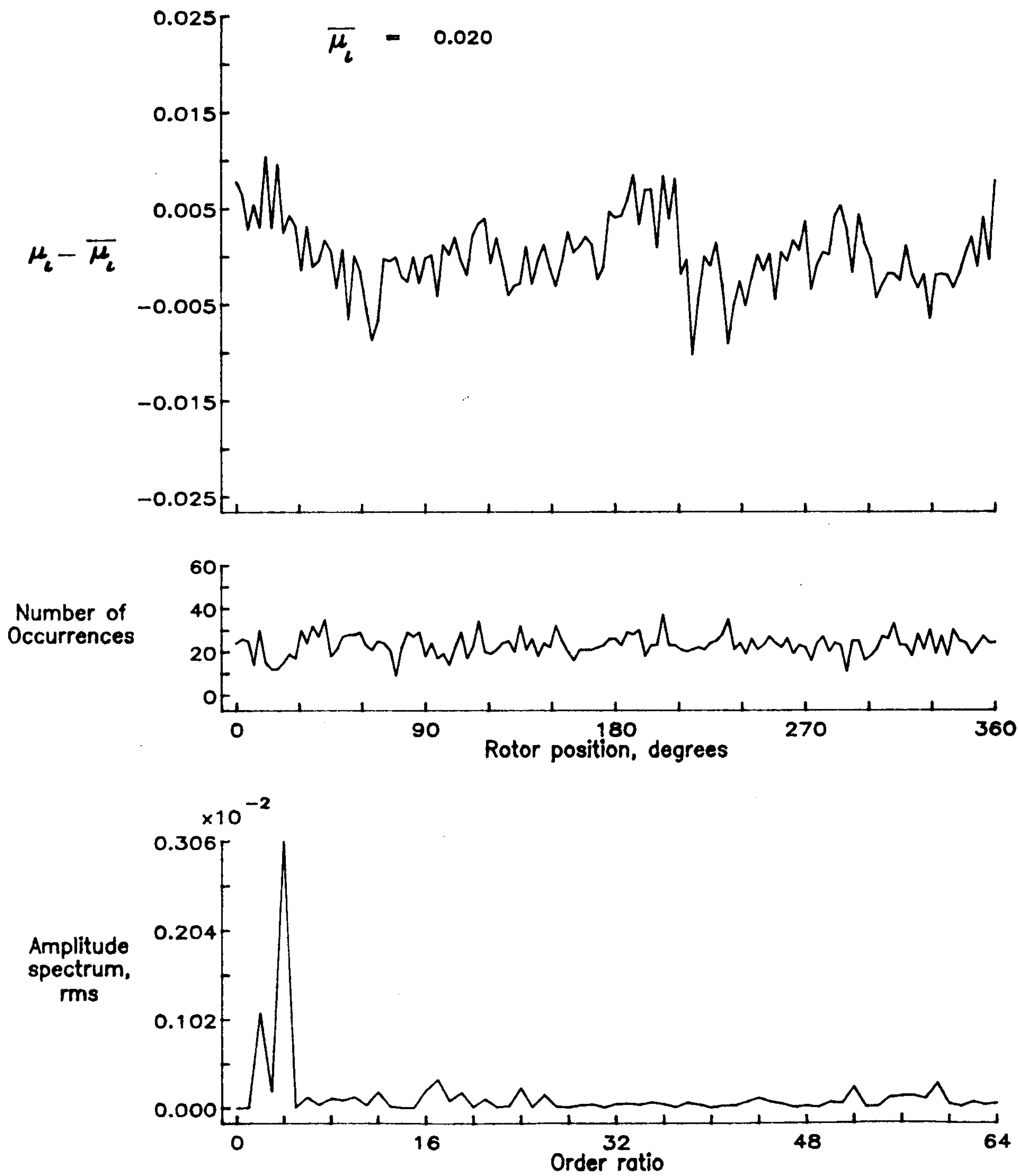


Figure 14.– Induced inflow velocity measured at 0 degrees and r/R of 0.40.

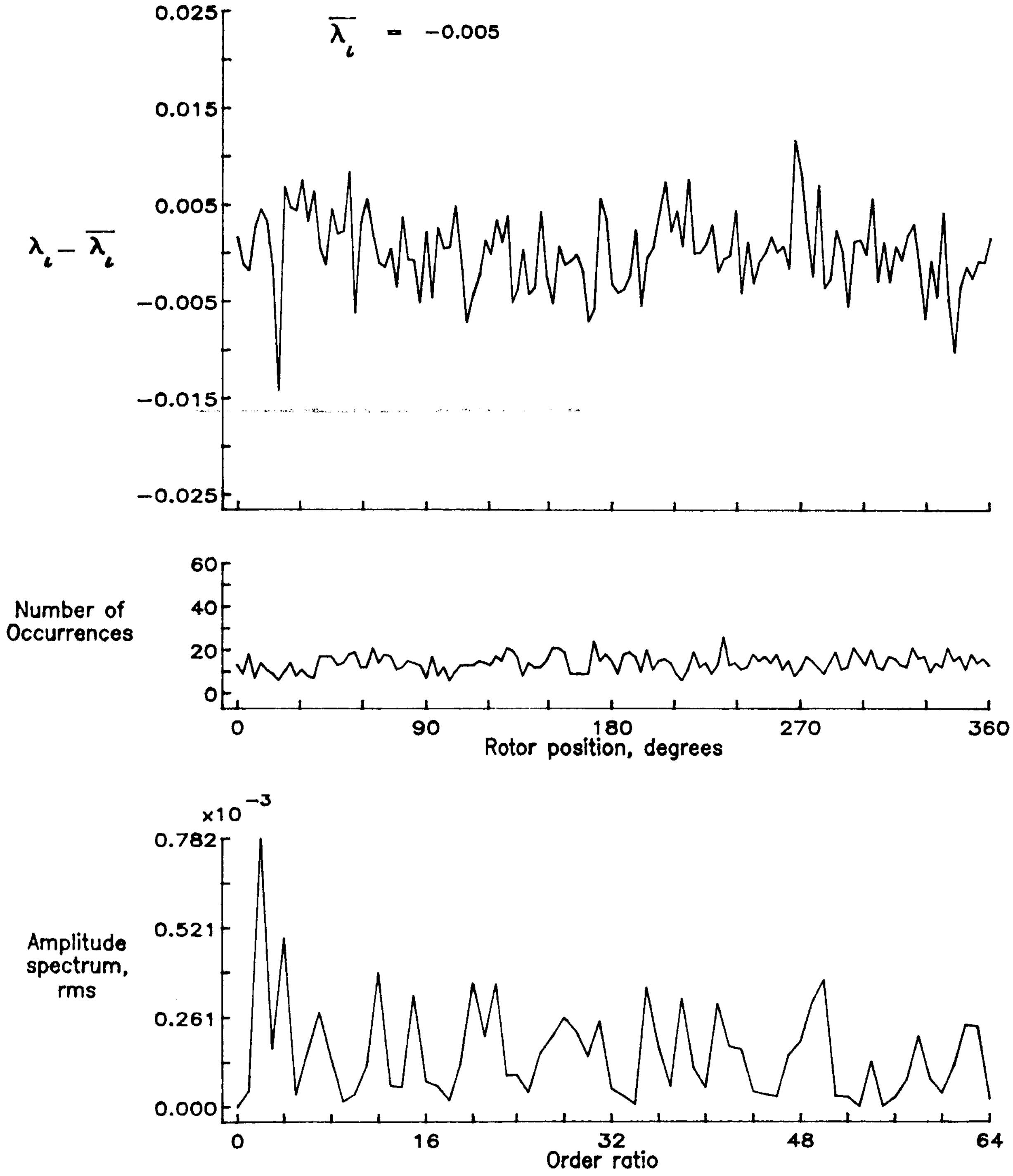


Figure 14.– Concluded.

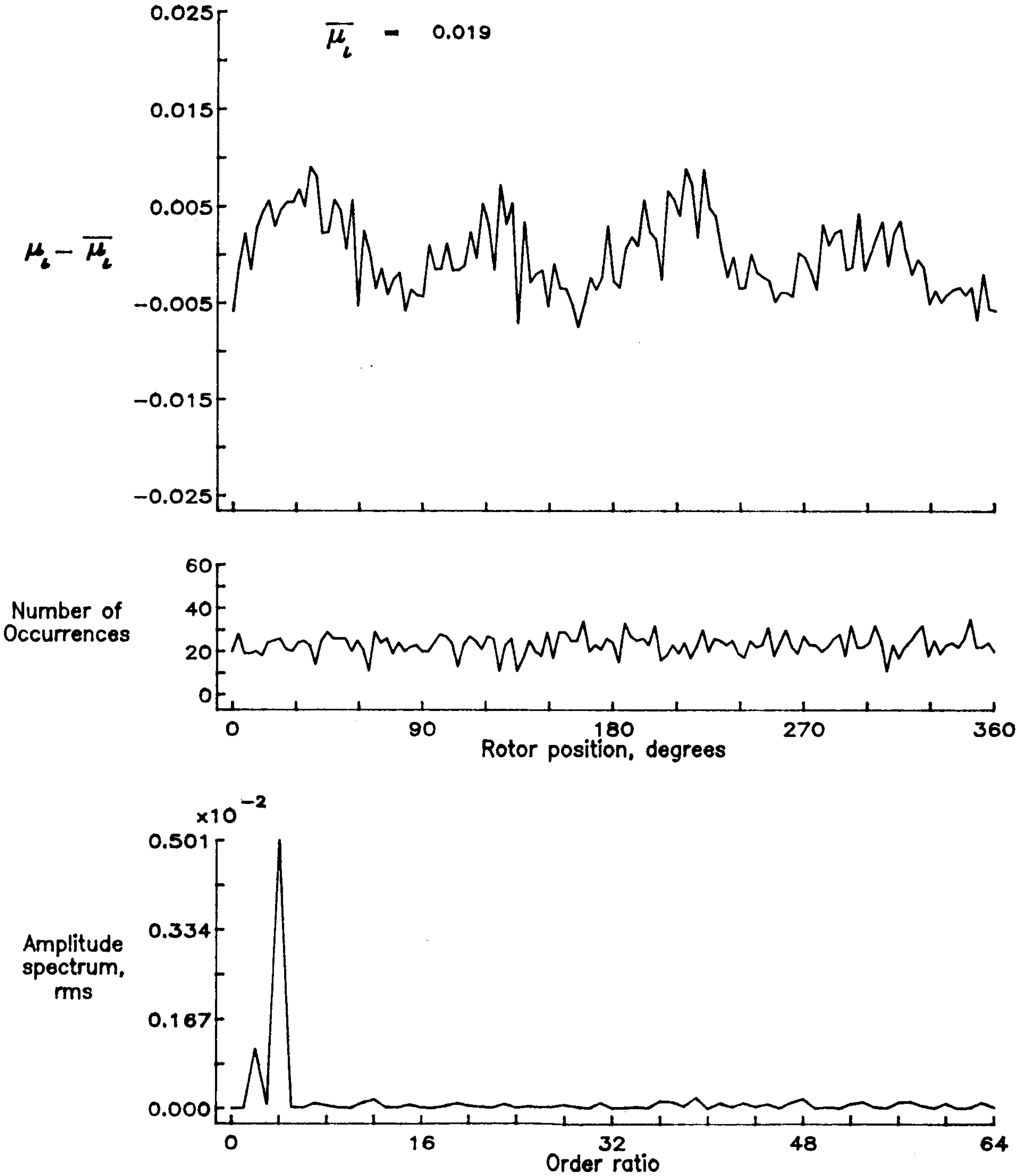


Figure 15.– Induced inflow velocity measured at 0 degrees and r/R of 0.50.

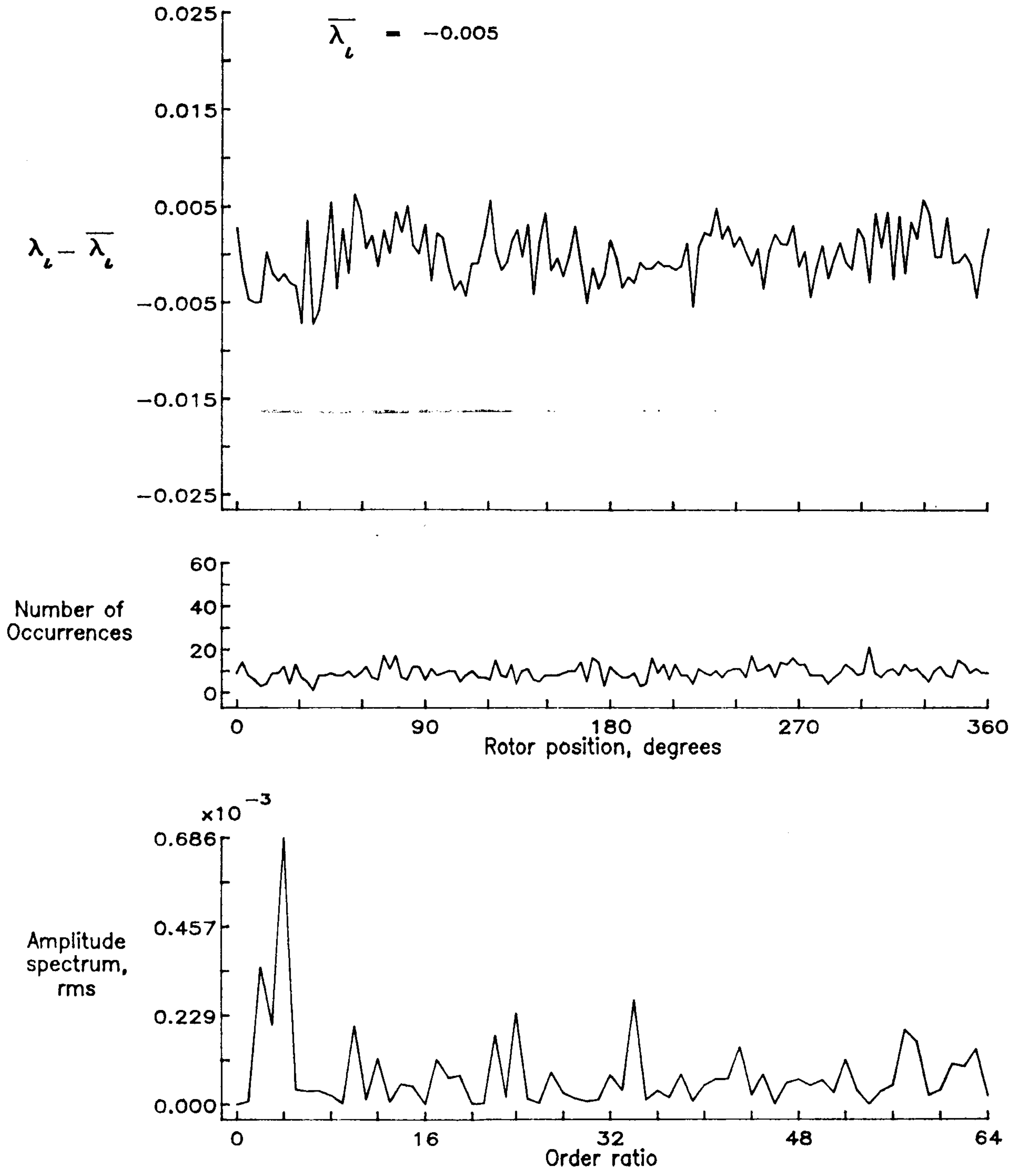


Figure 15.– Concluded.

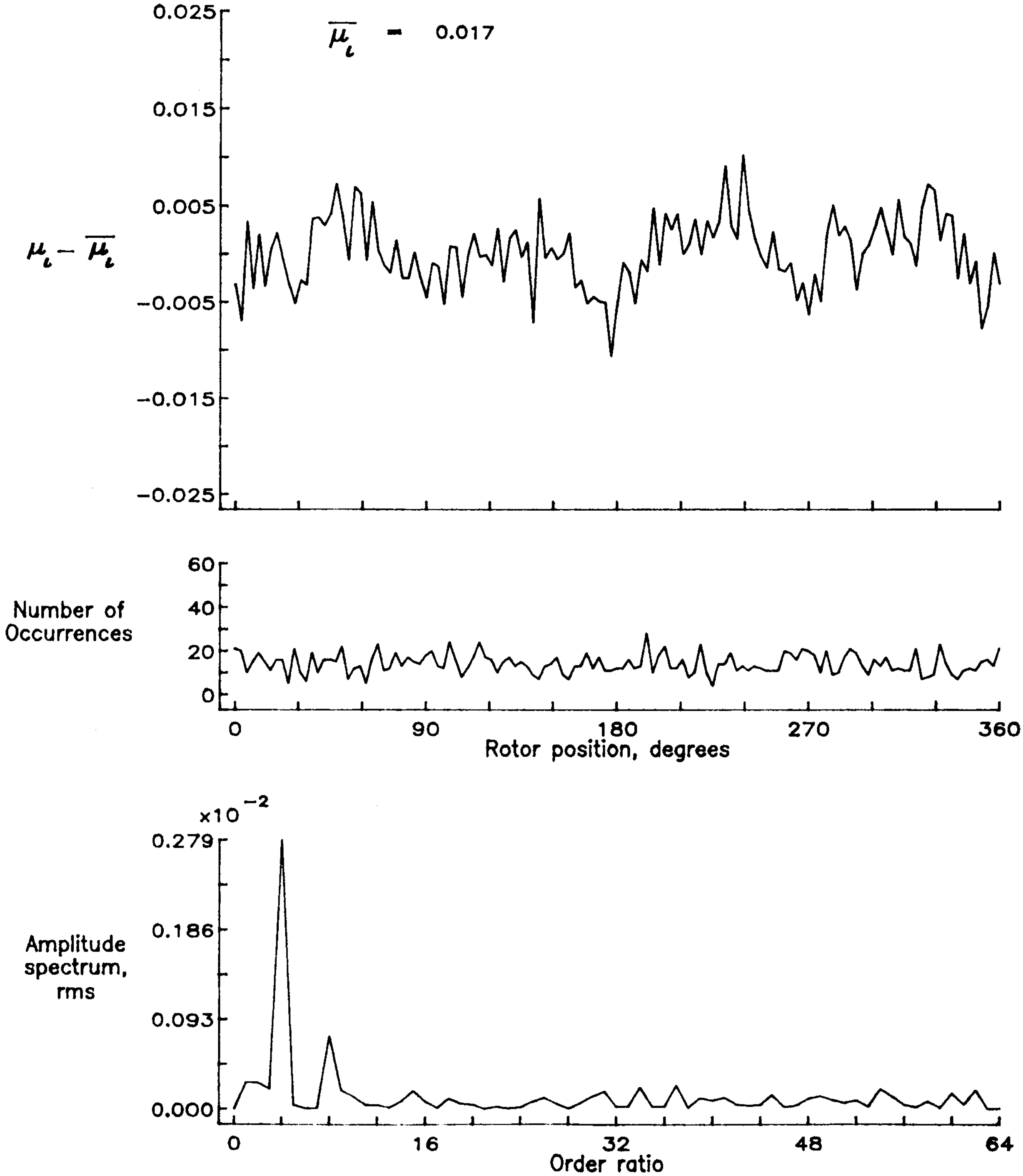


Figure 16.– Induced inflow velocity measured at 0 degrees and r/R of 0.60.

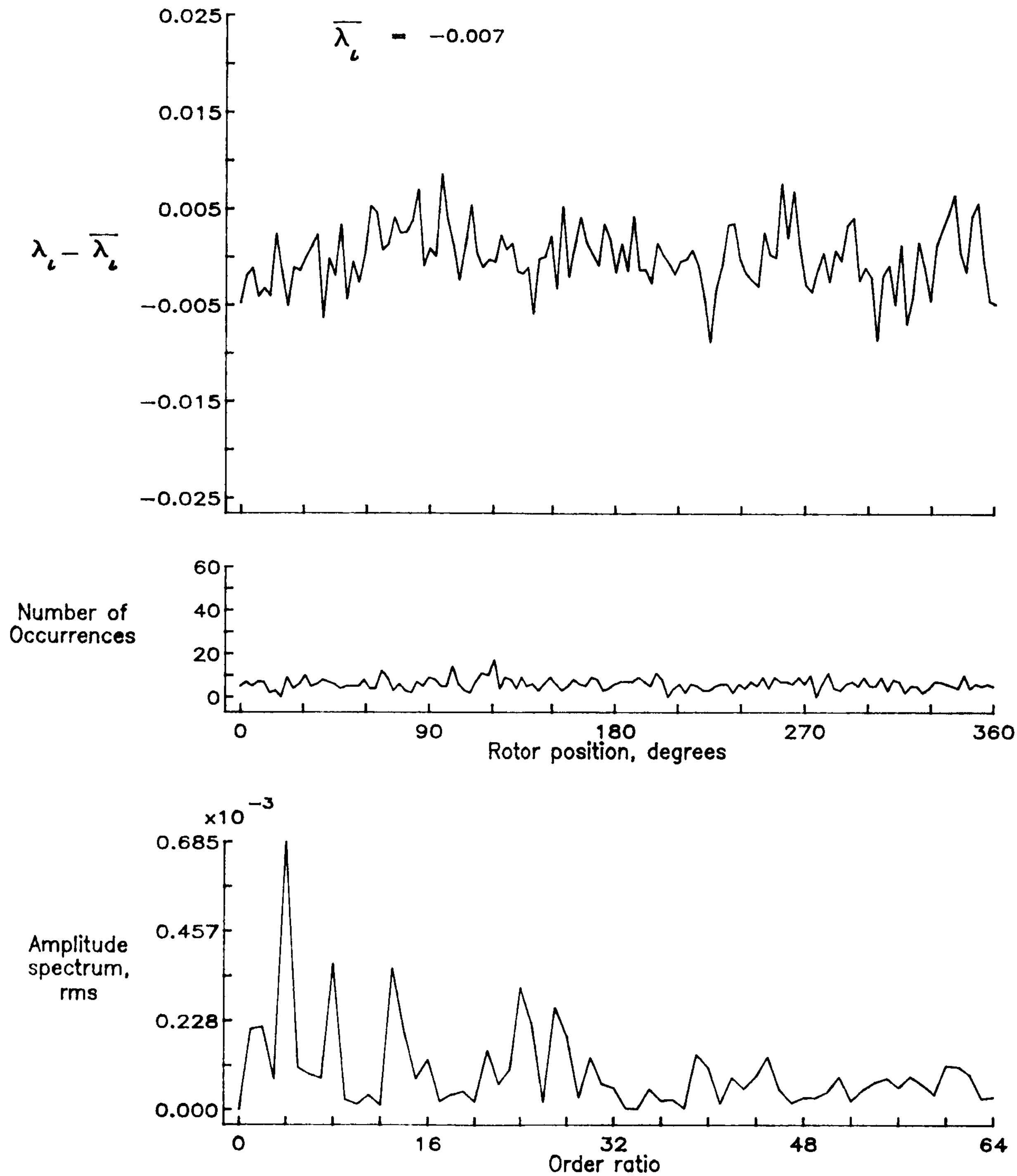


Figure 16.– Concluded.

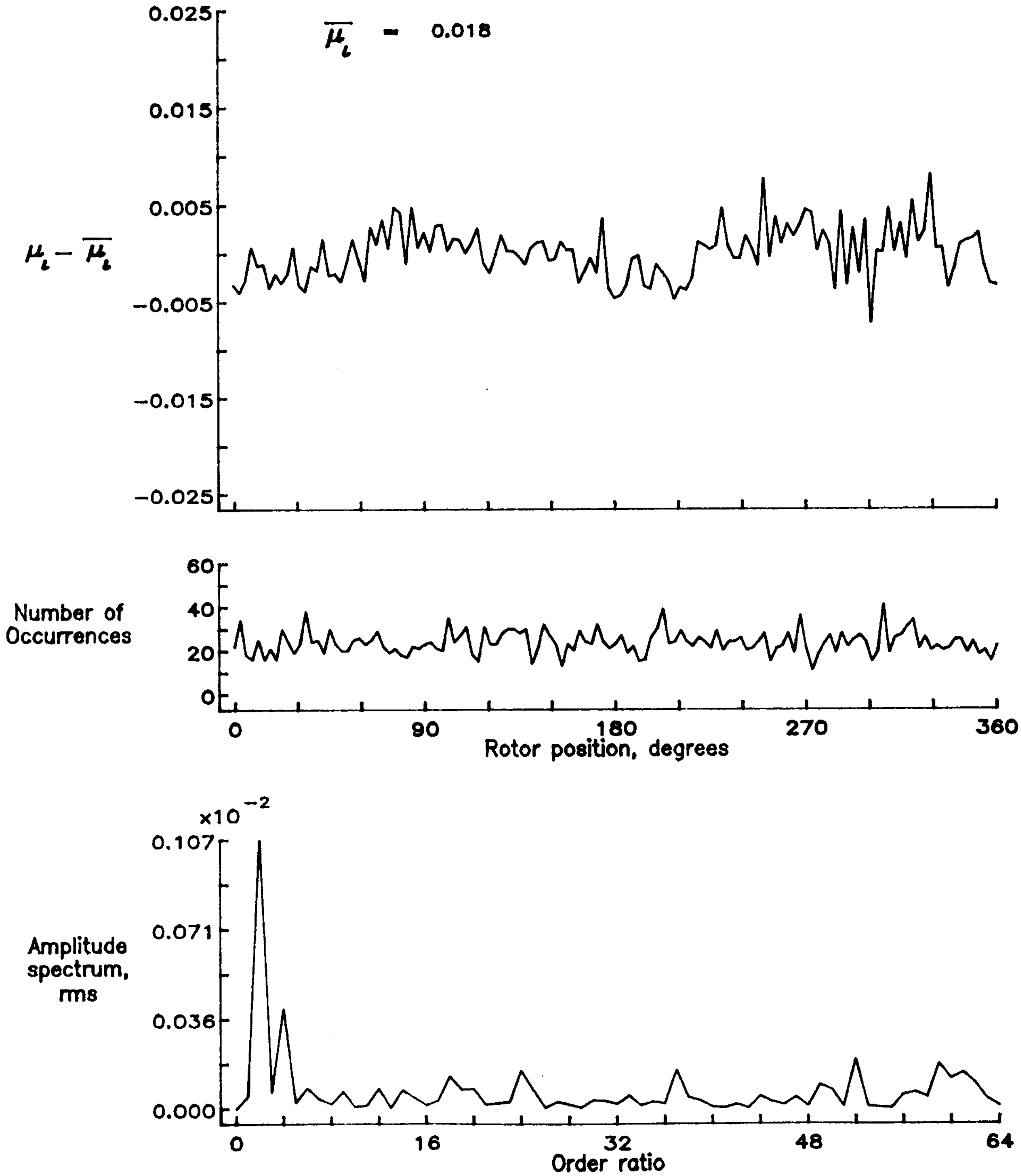


Figure 17.– Induced inflow velocity measured at 0 degrees and r/R of 0.70.

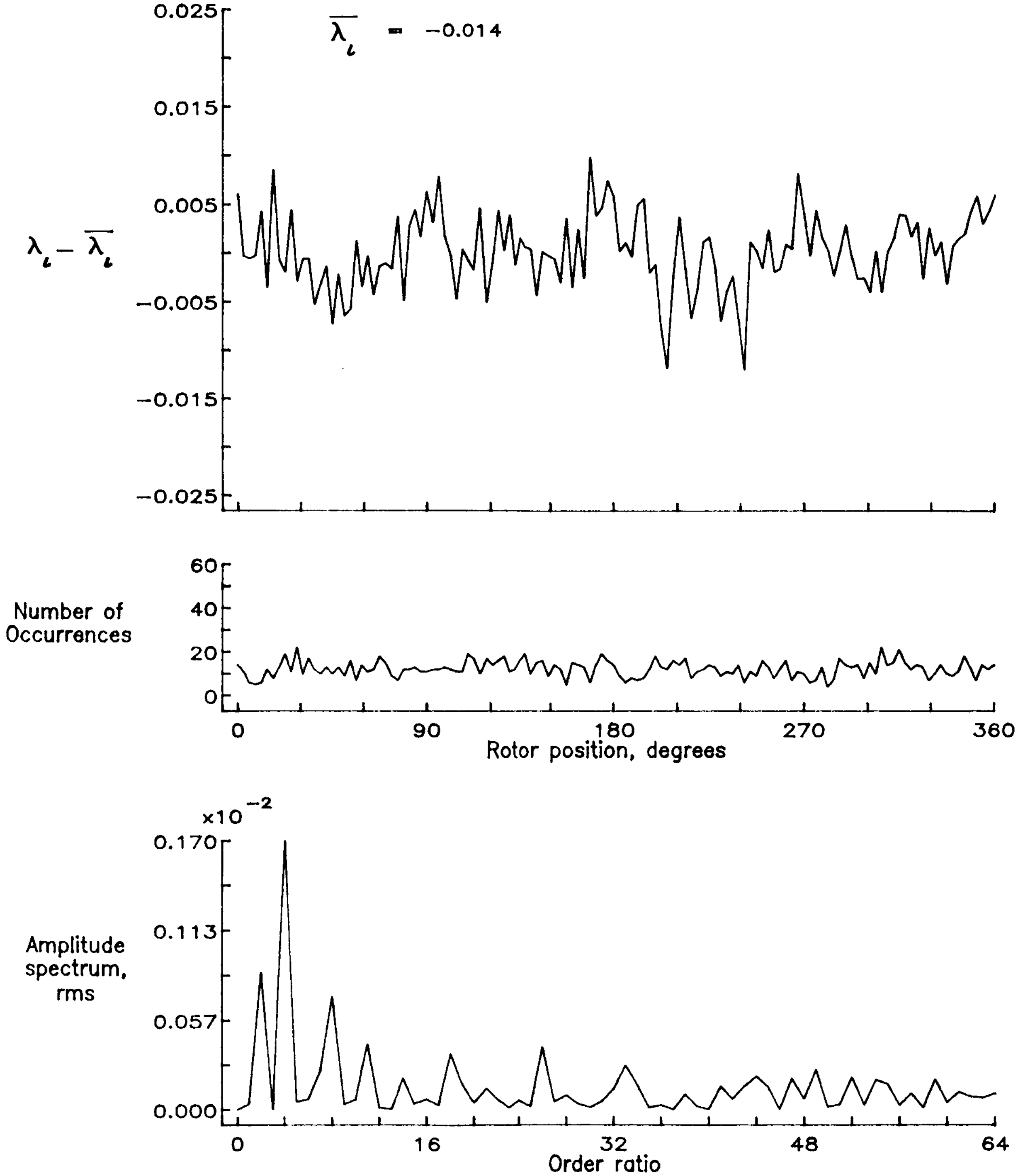


Figure 17.– Concluded.

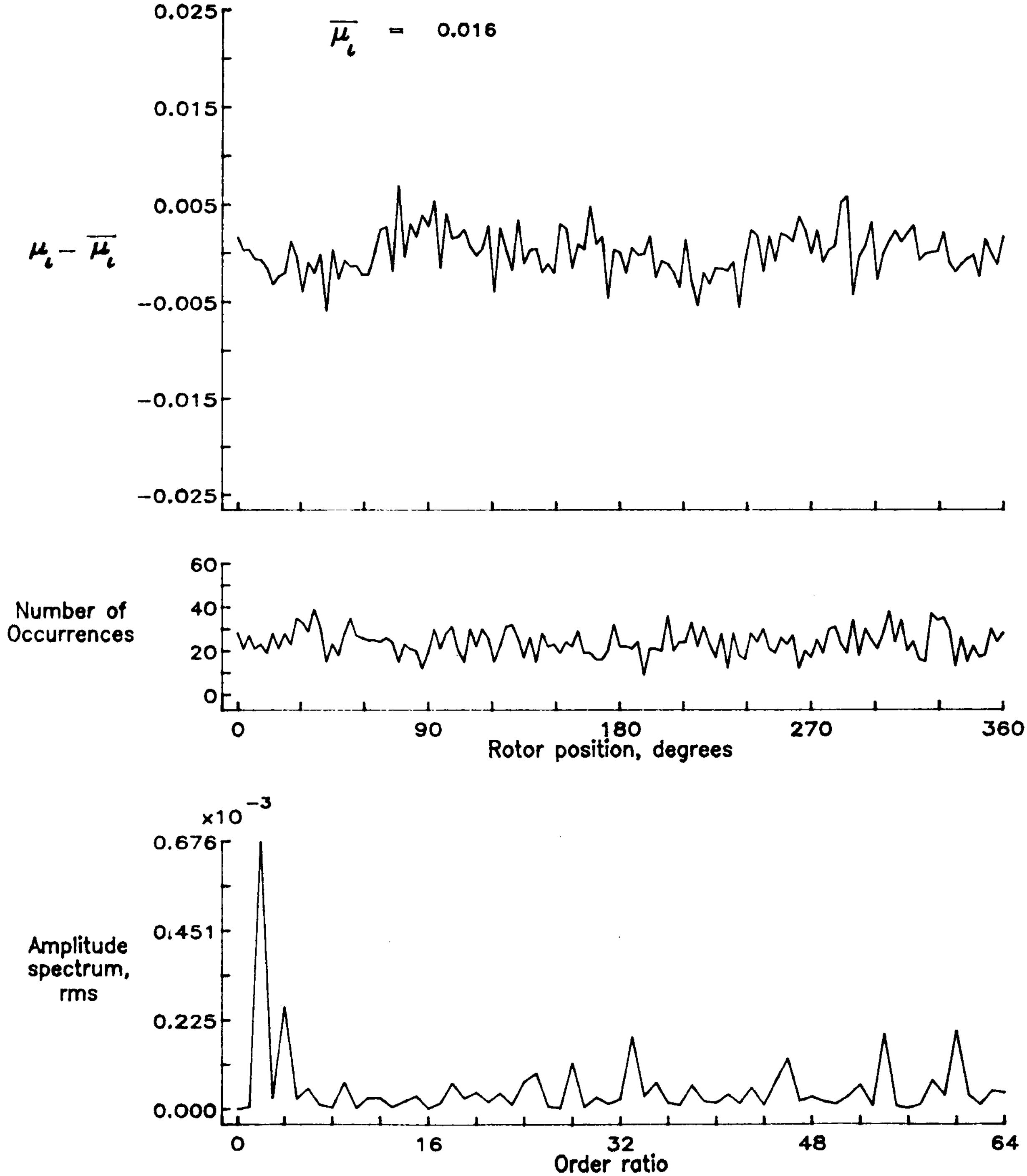


Figure 18.– Induced inflow velocity measured at 0 degrees and r/R of 0.74.

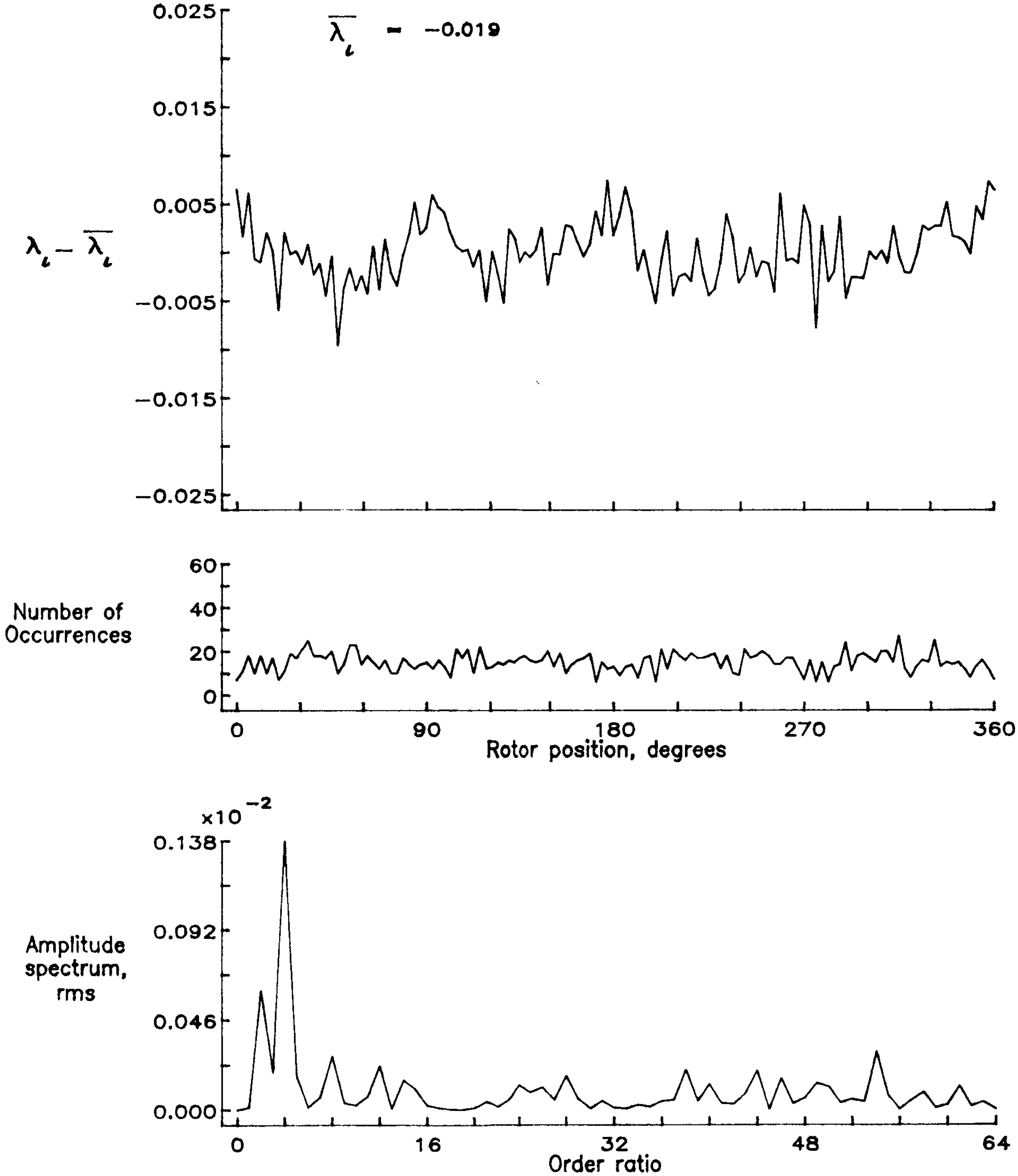


Figure 18.– Concluded.

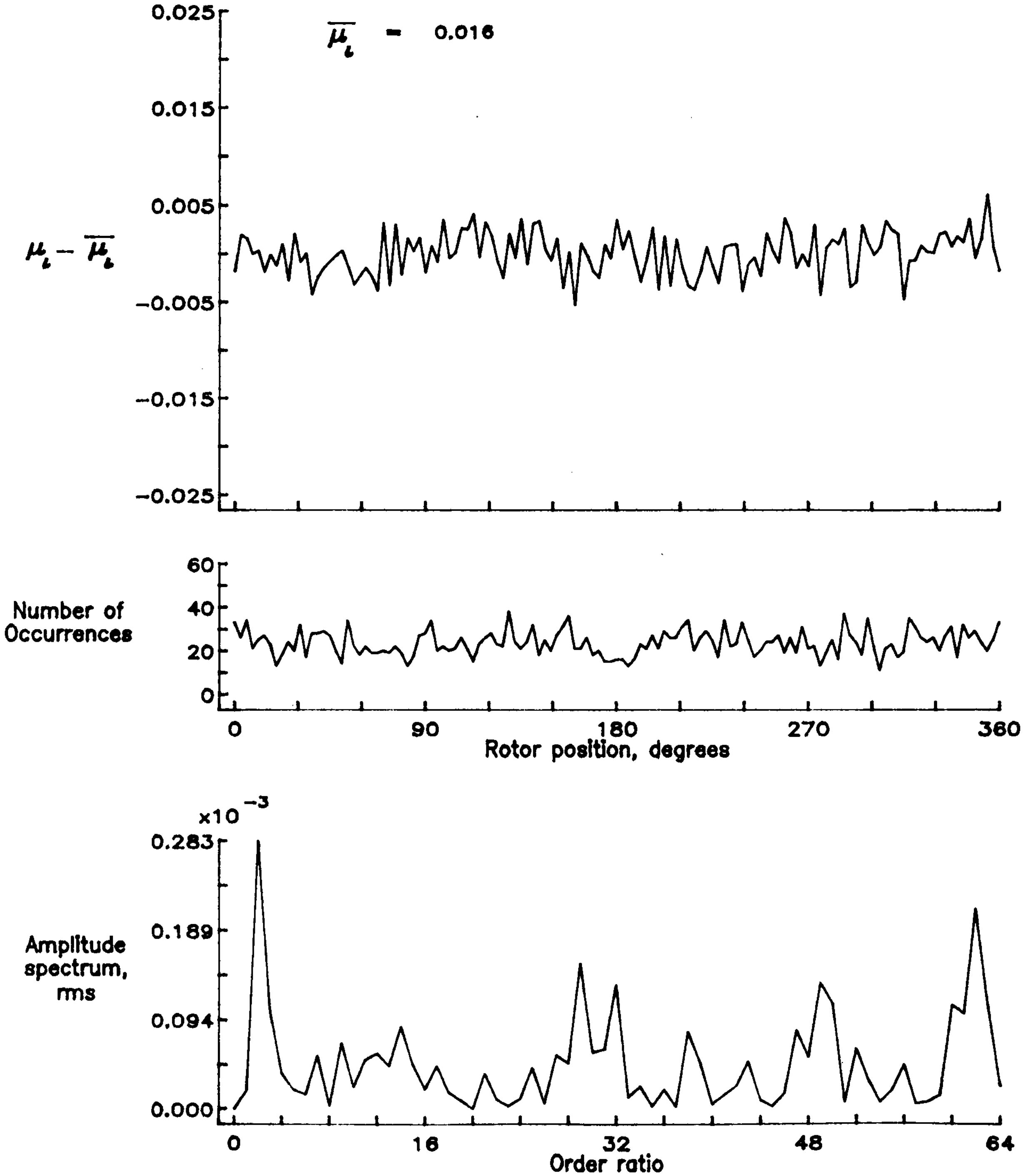


Figure 19.– Induced inflow velocity measured at 0 degrees and r/R of 0.78.

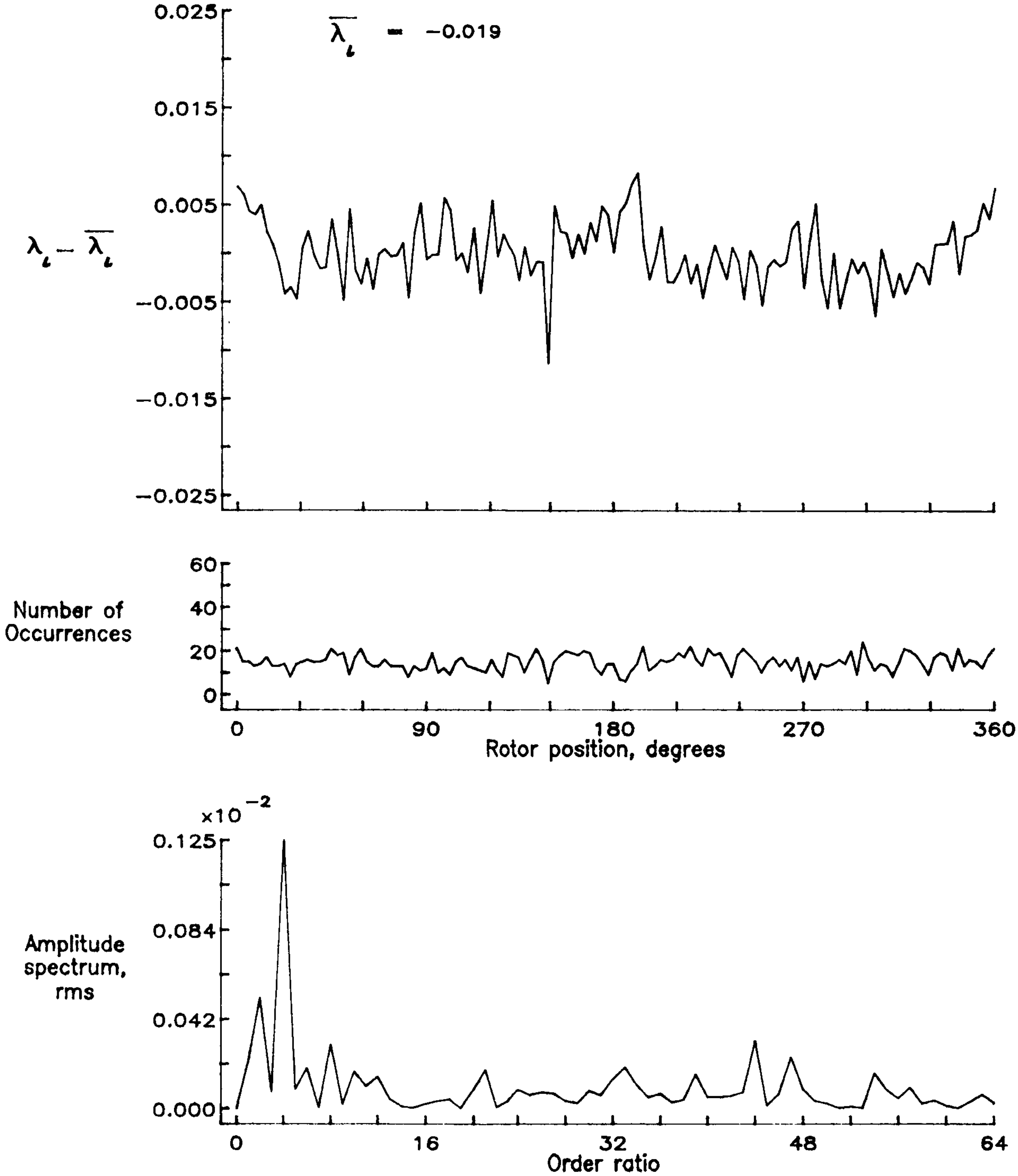


Figure 19.– Concluded.

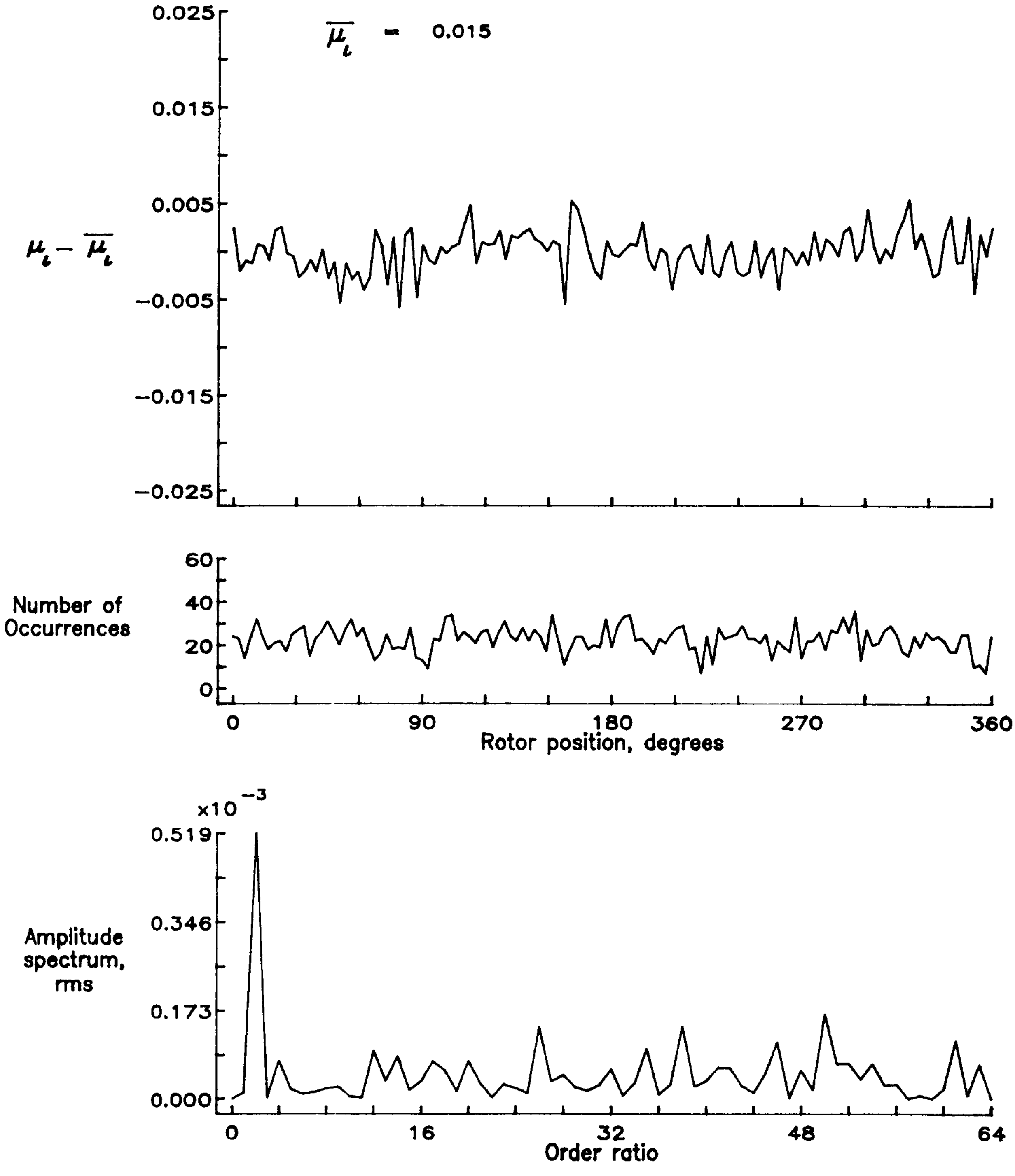


Figure 20.– Induced inflow velocity measured at 0 degrees and r/R of 0.82.

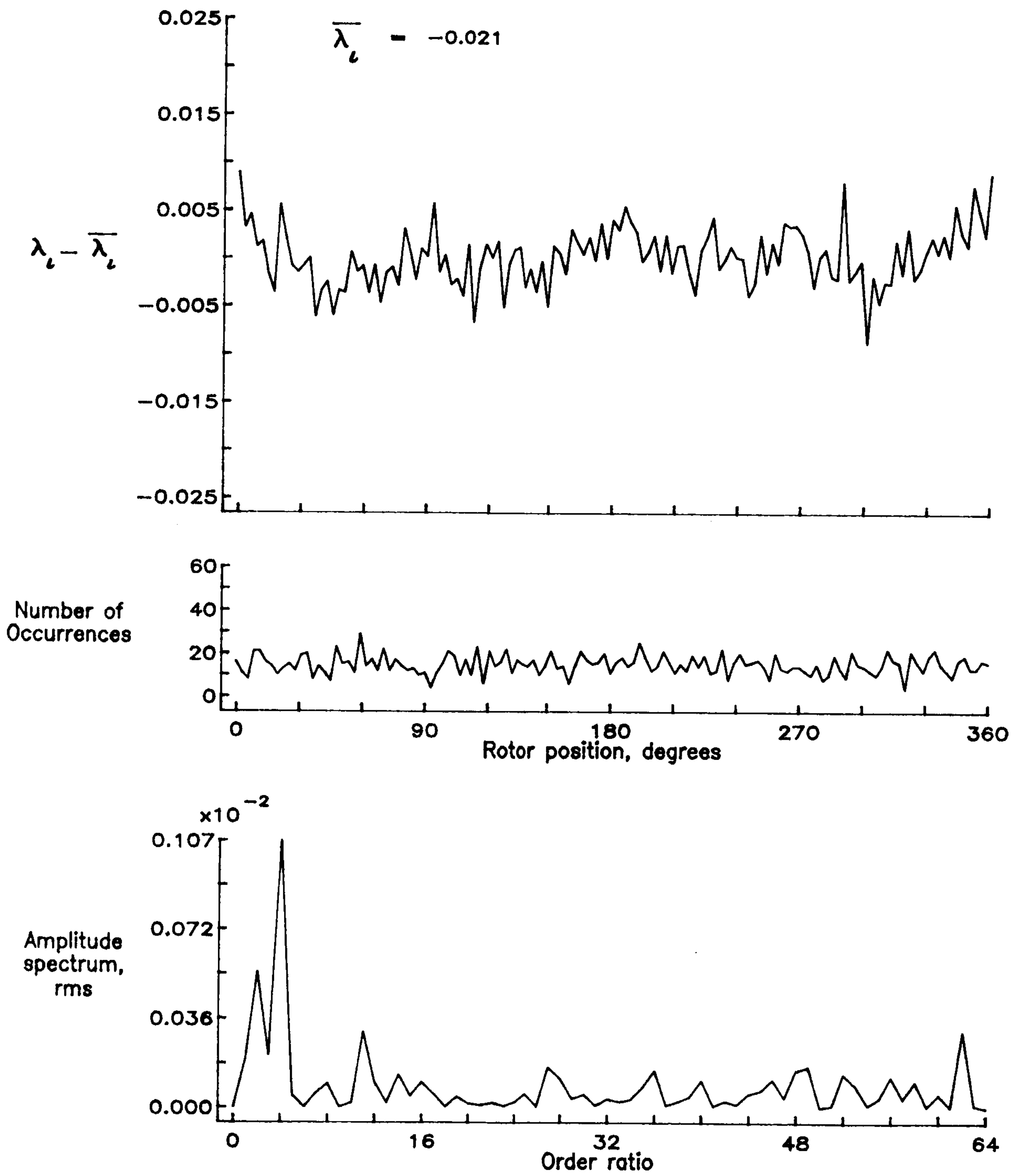


Figure 20.– Concluded.

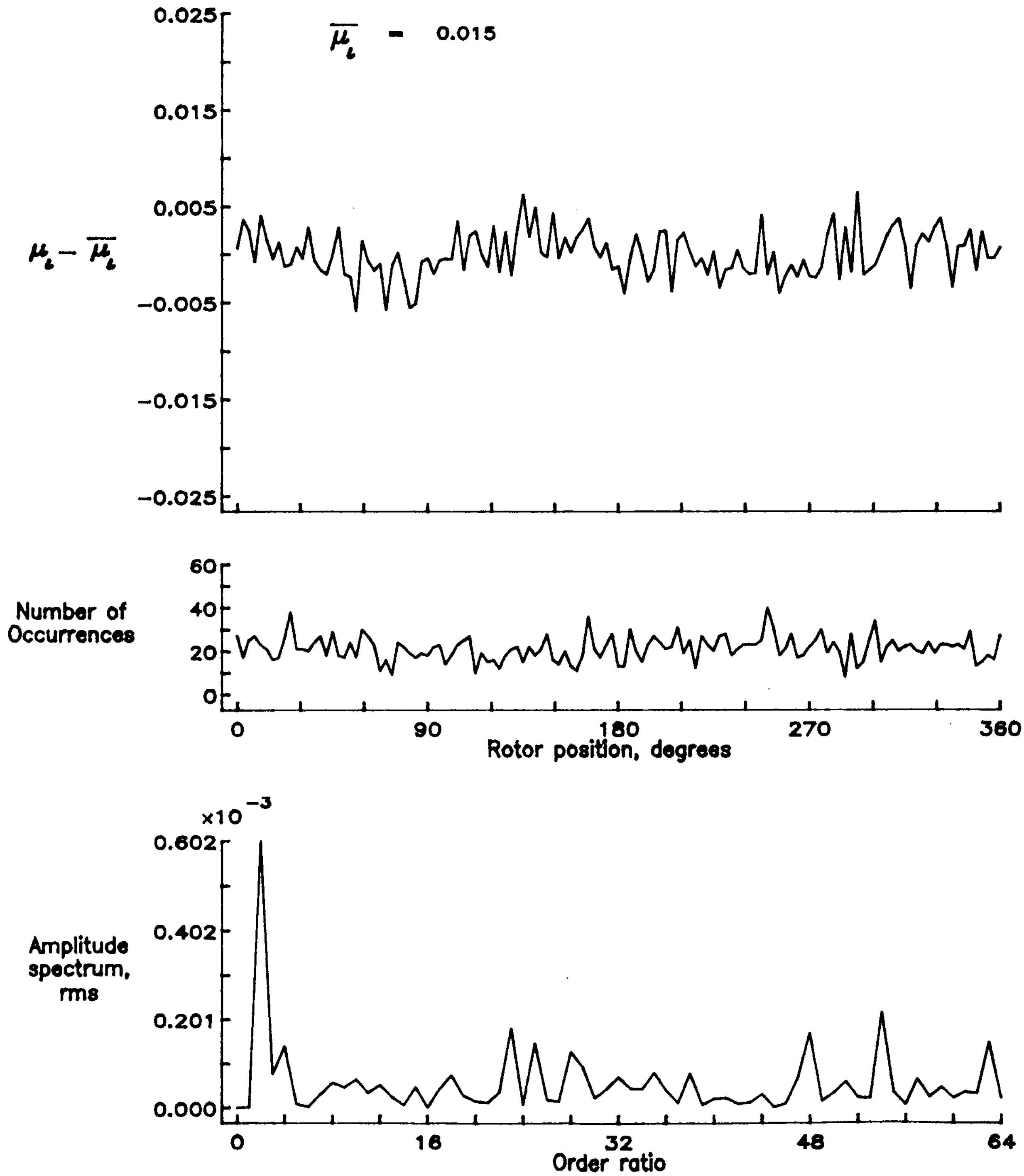


Figure 21.– Induced inflow velocity measured at 0 degrees and r/R of 0.86.

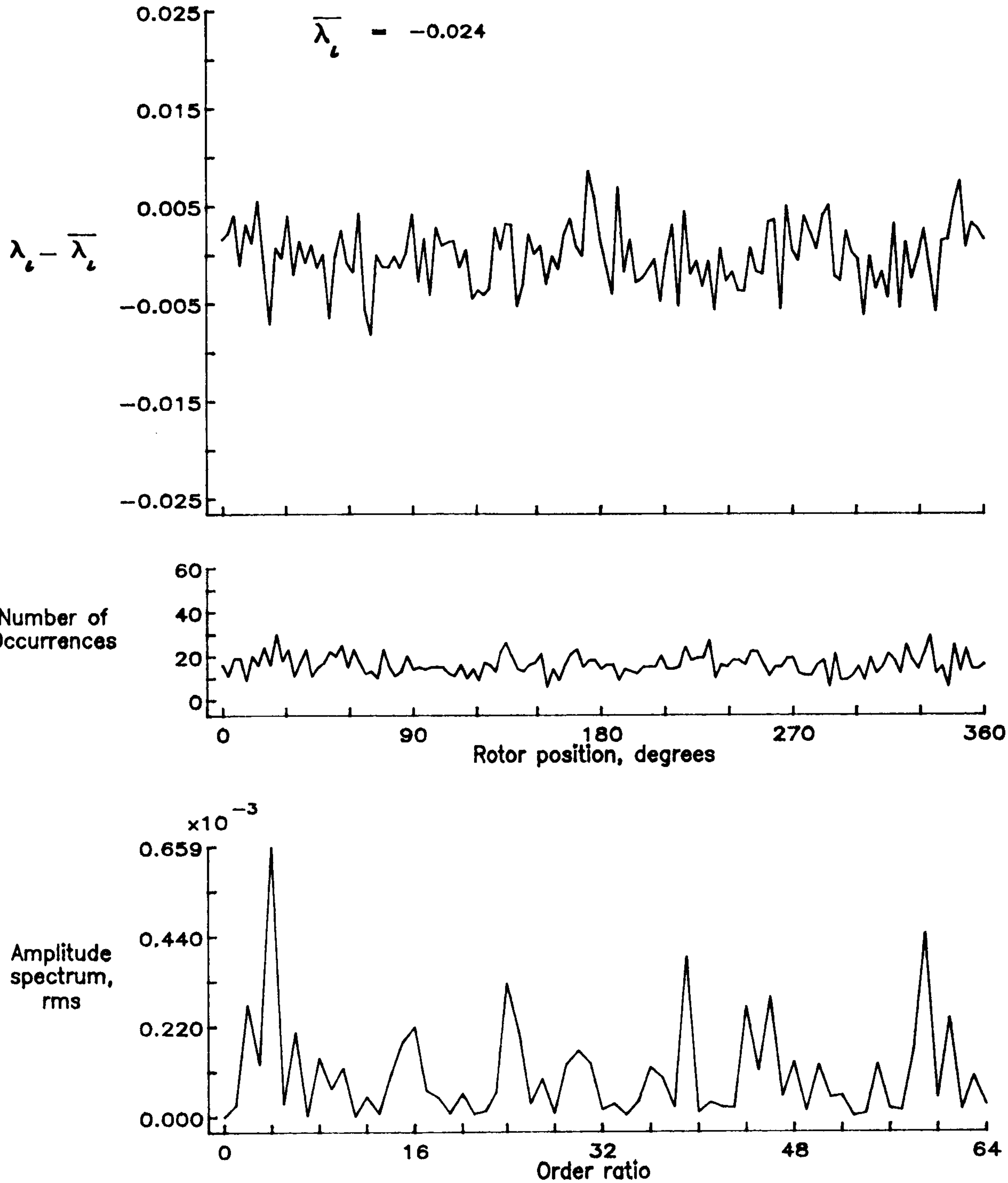


Figure 21.– Concluded.

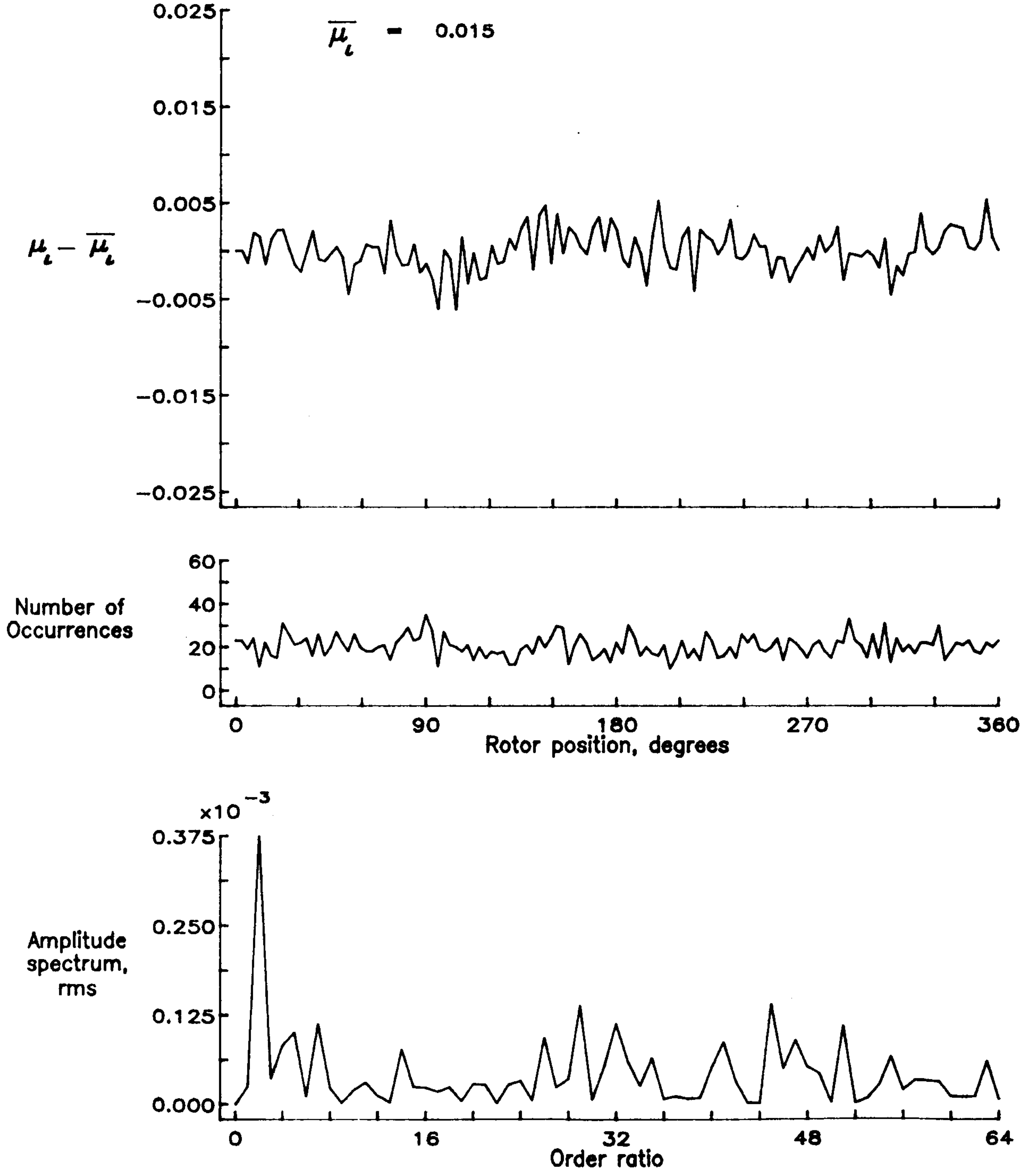


Figure 22.— Induced inflow velocity measured at 0 degrees and r/R of 0.90.

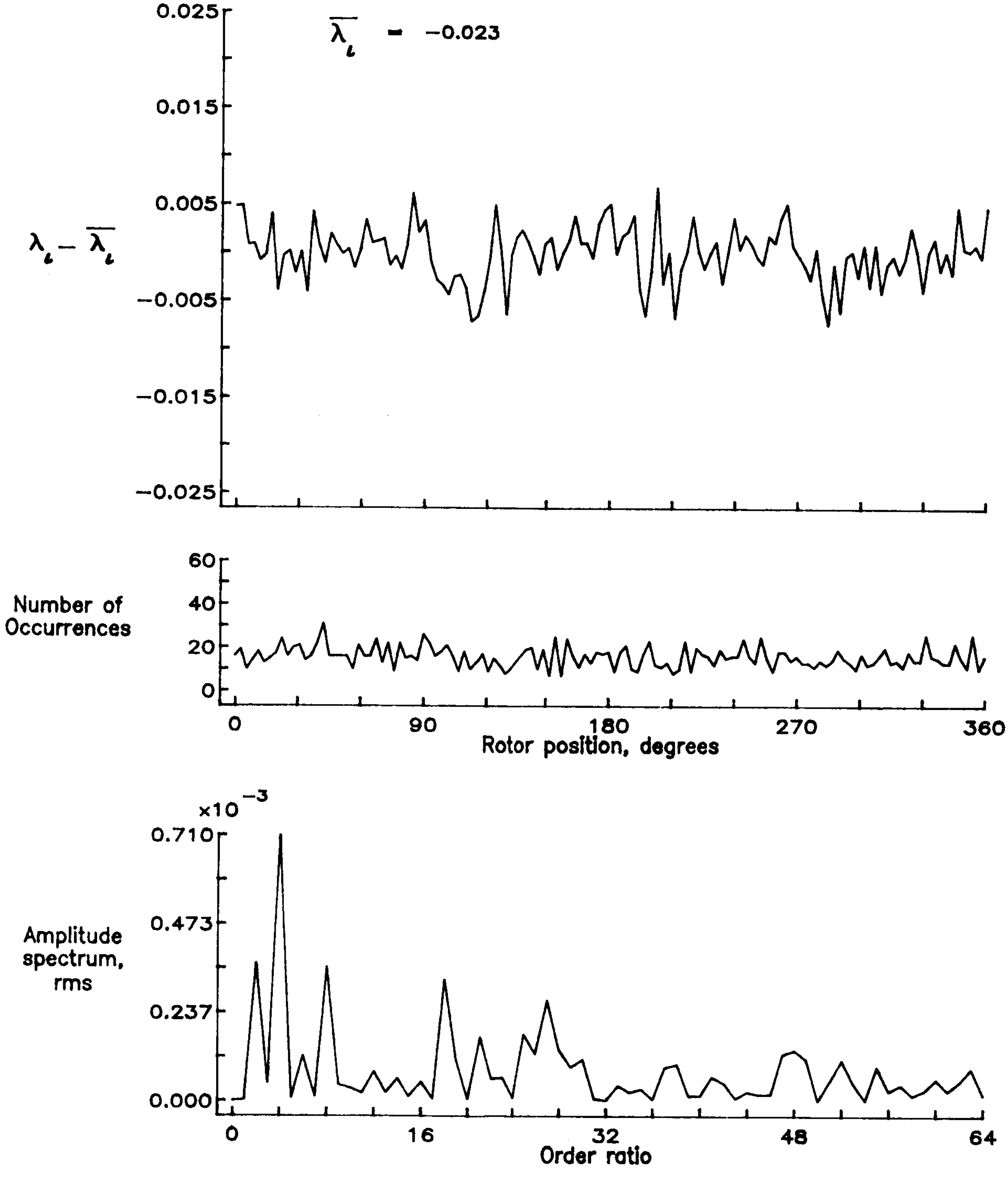


Figure 22.– Concluded.

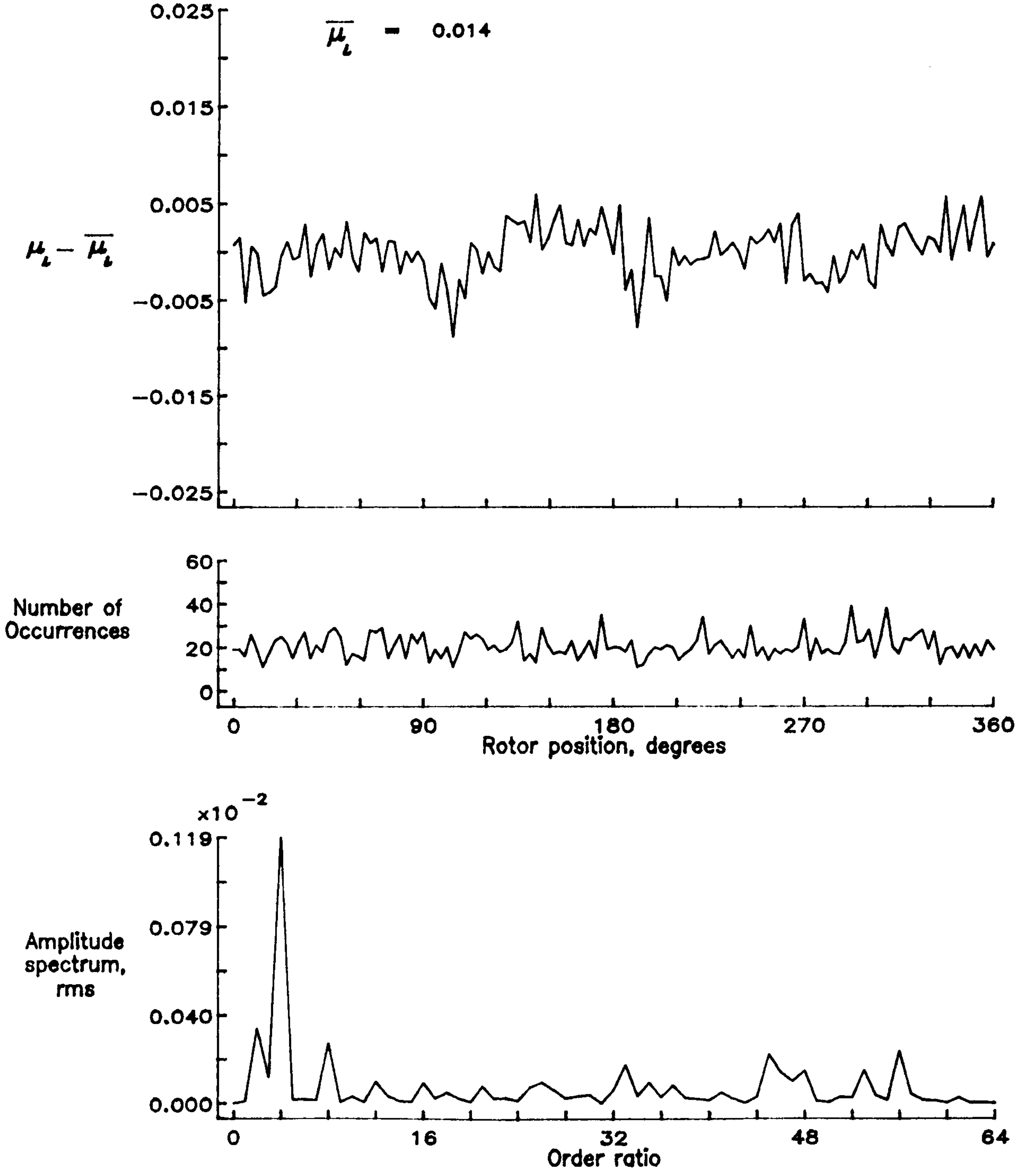
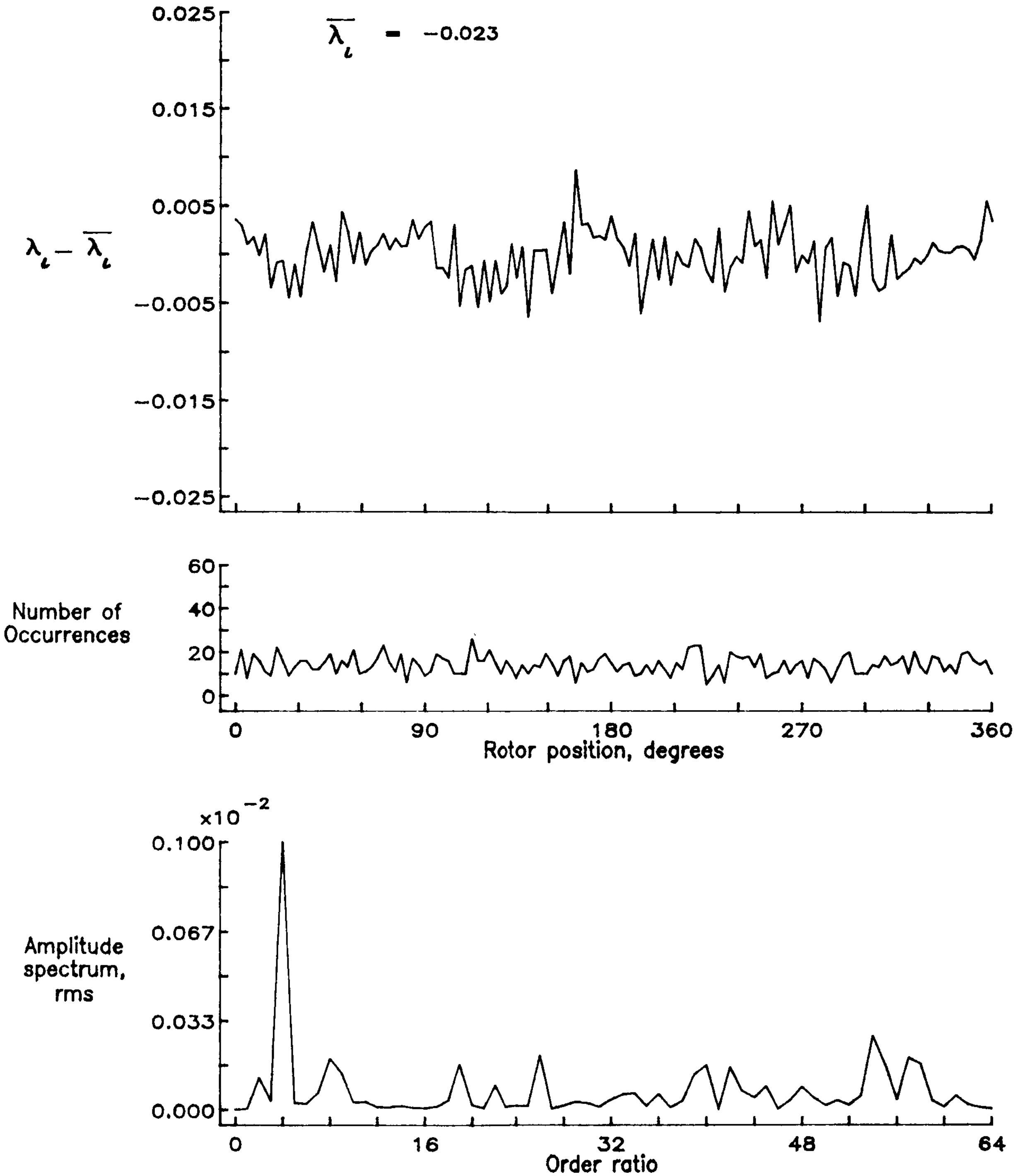


Figure 23.– Induced inflow velocity measured at 0 degrees and r/R of 0.94.



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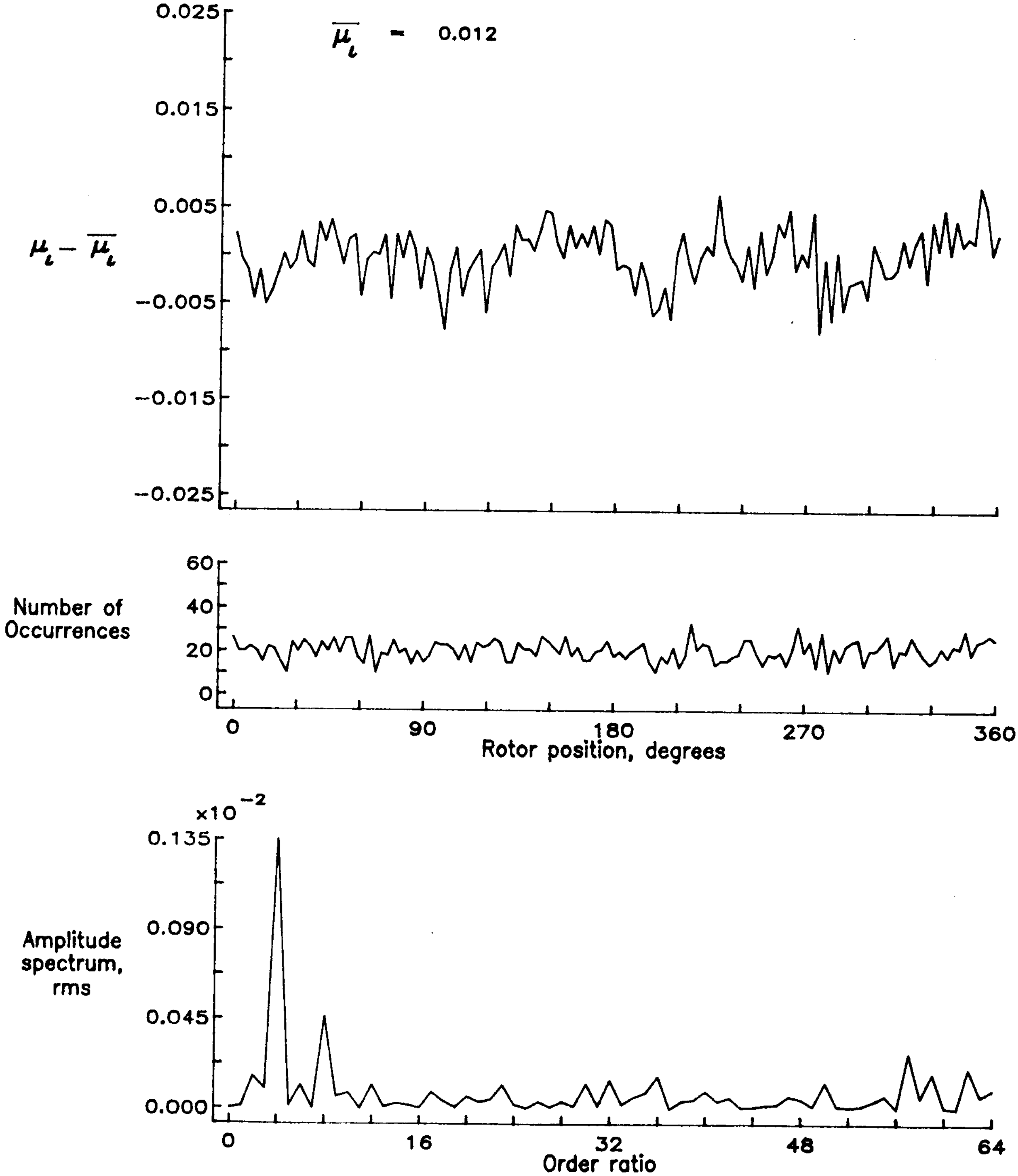
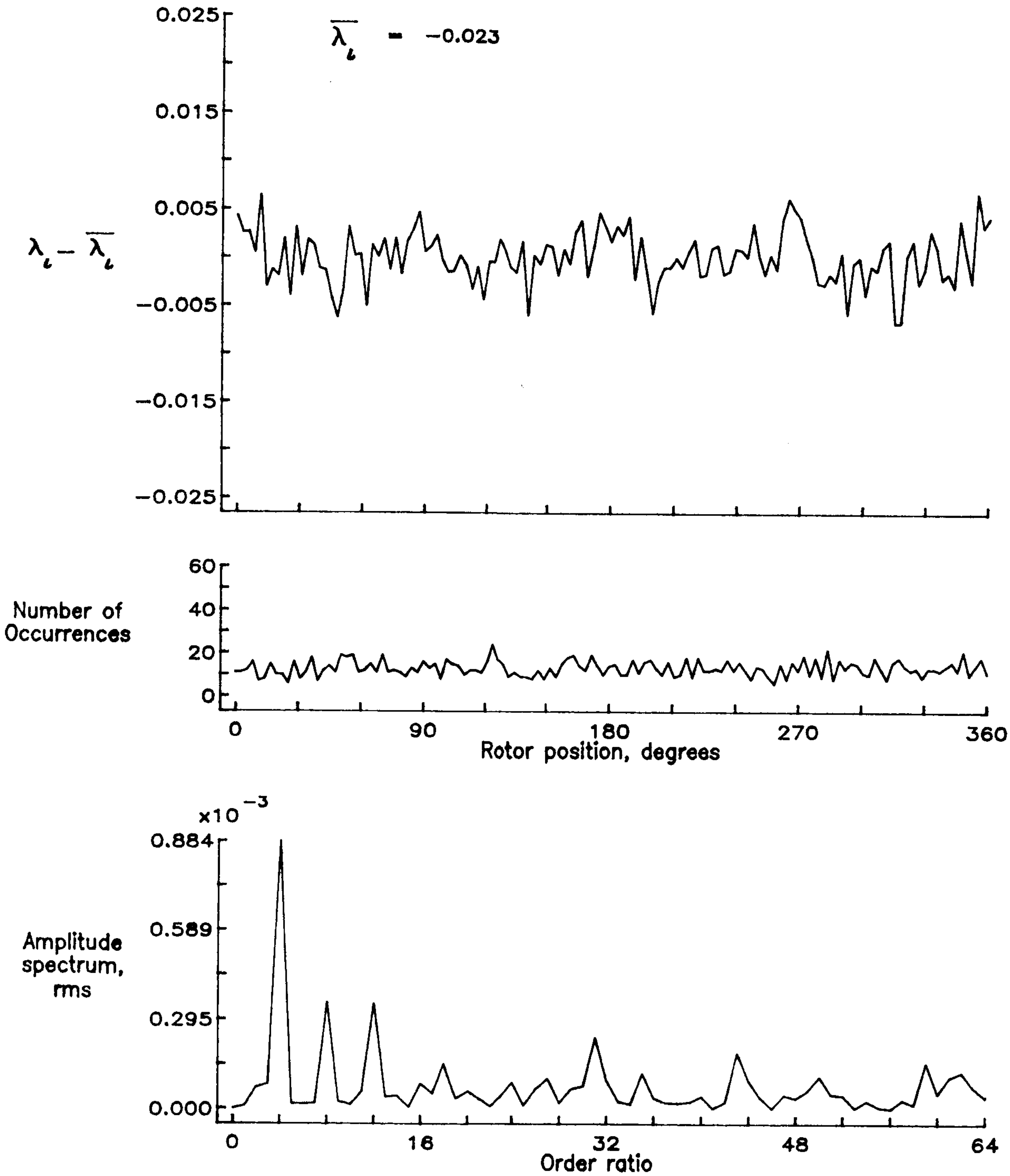


Figure 24.– Induced inflow velocity measured at 0 degrees and r/R of 0.98.



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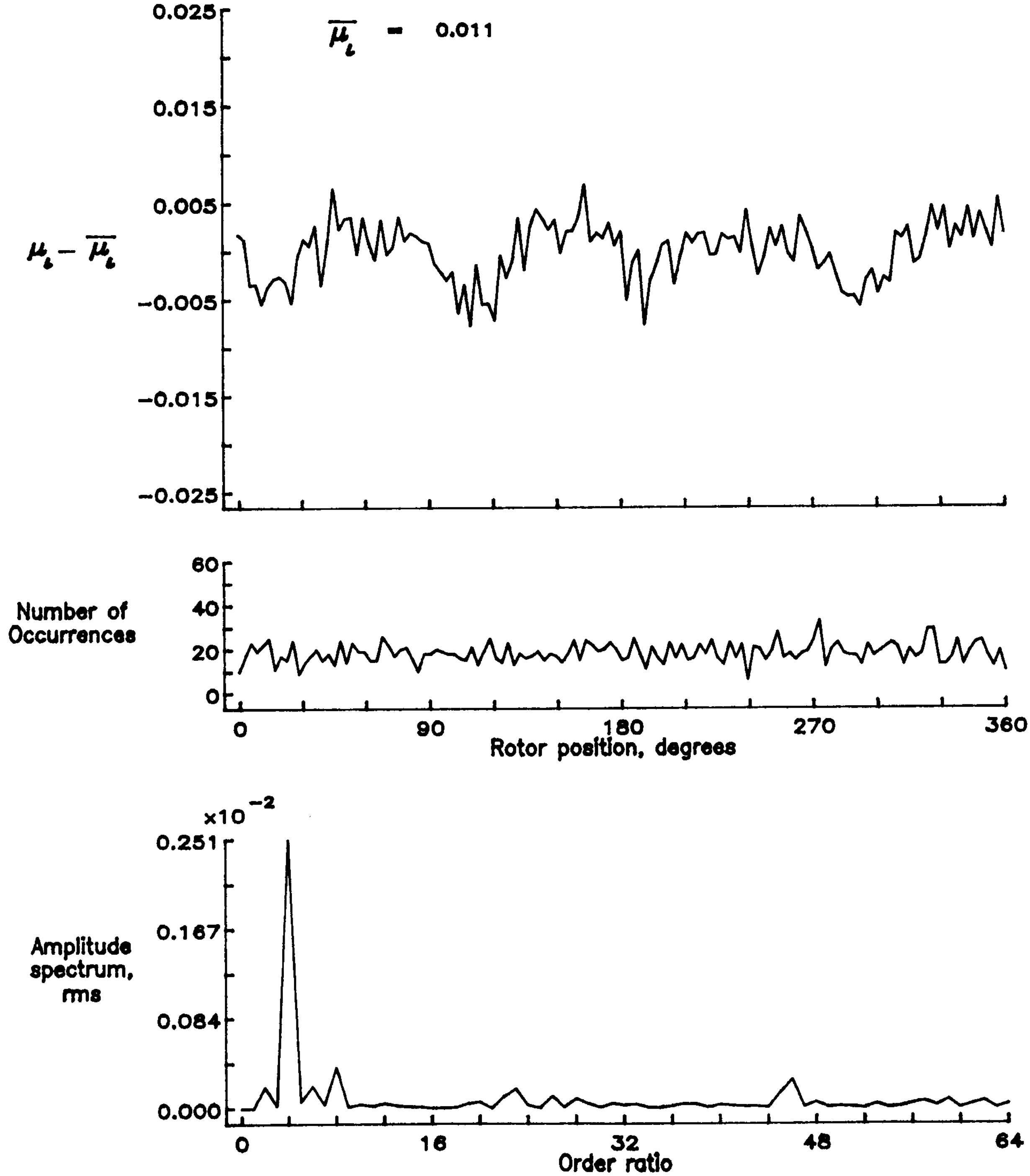
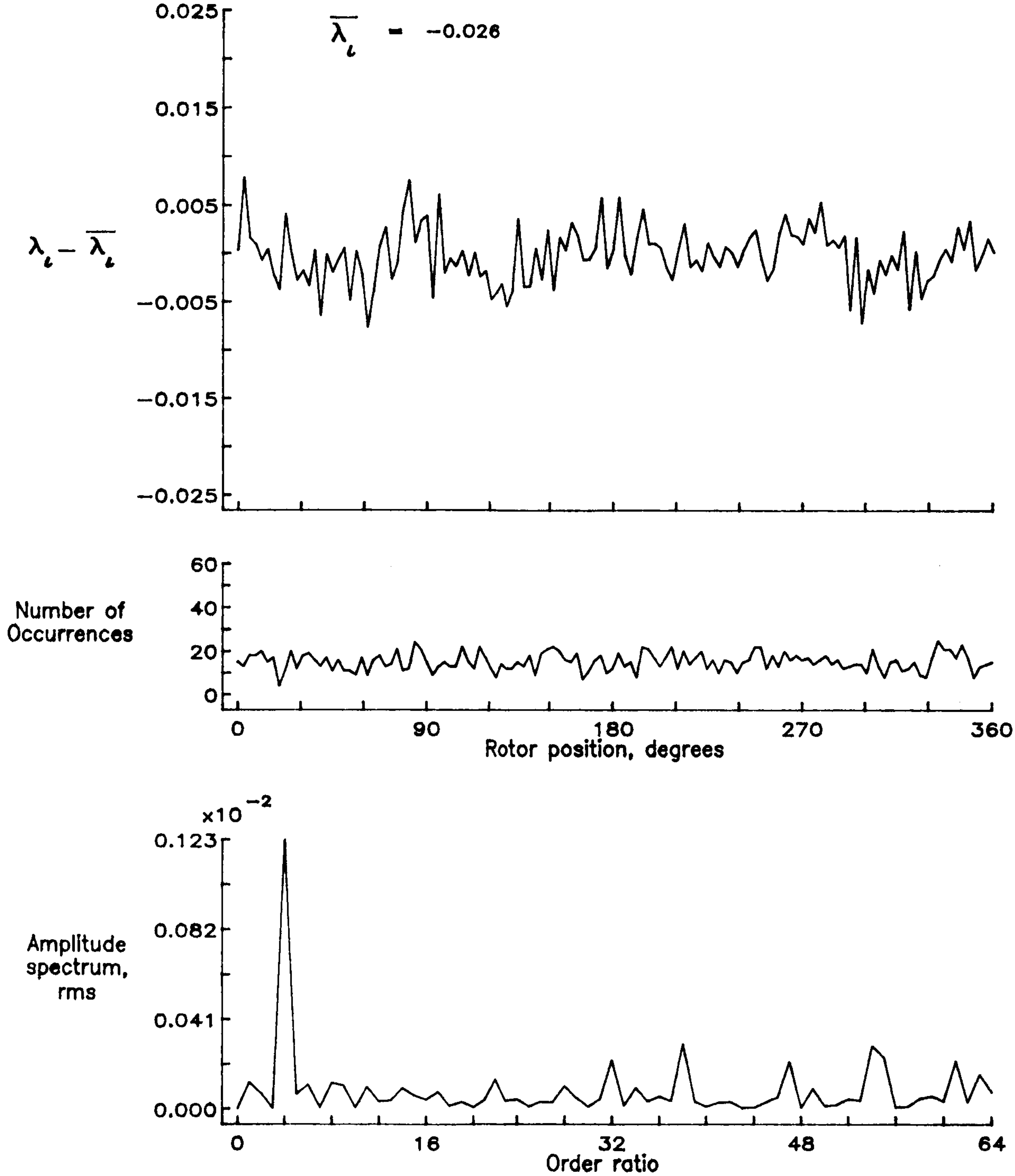


Figure 25.– Induced inflow velocity measured at 0 degrees and r/R of 1.02.



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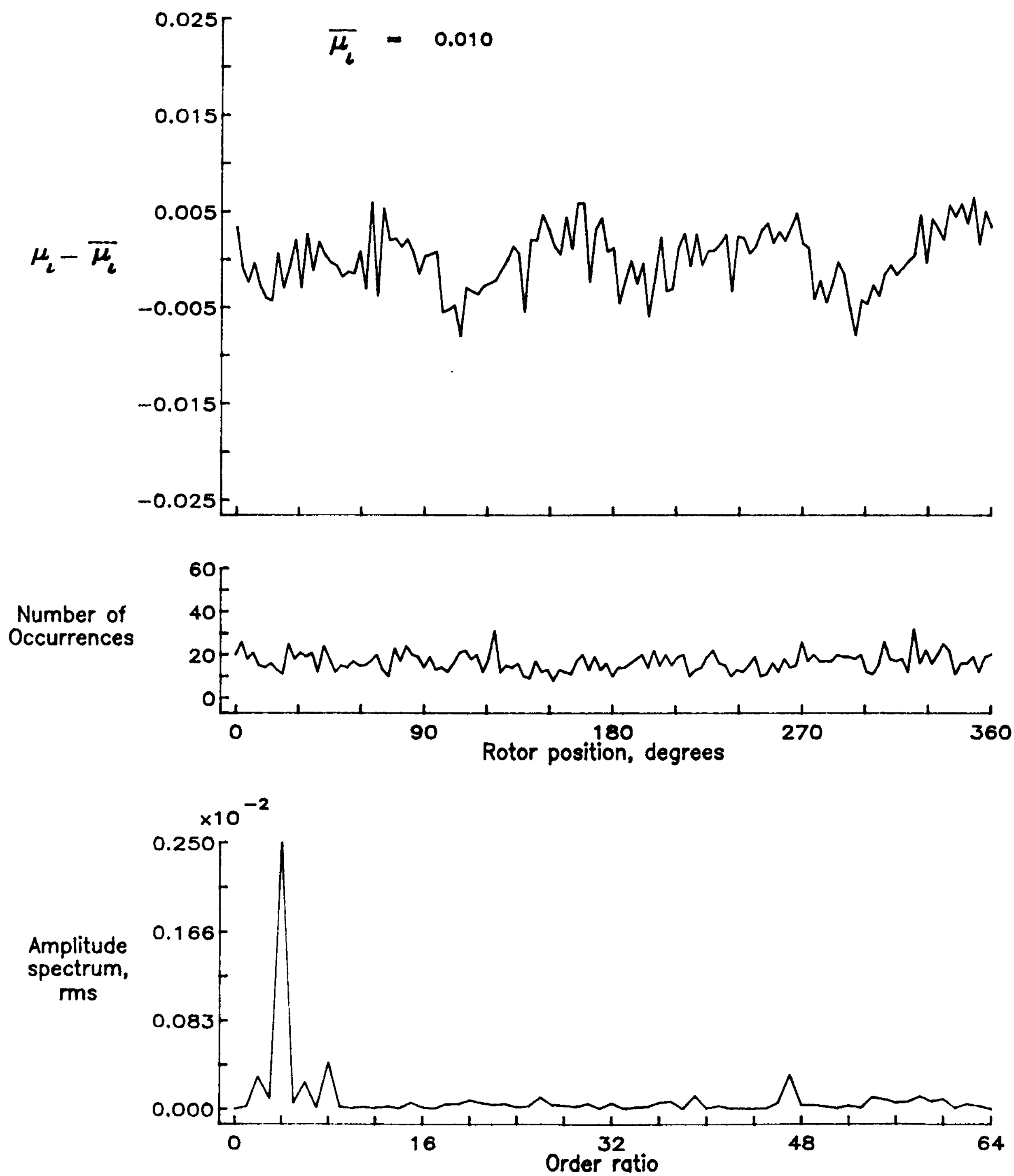
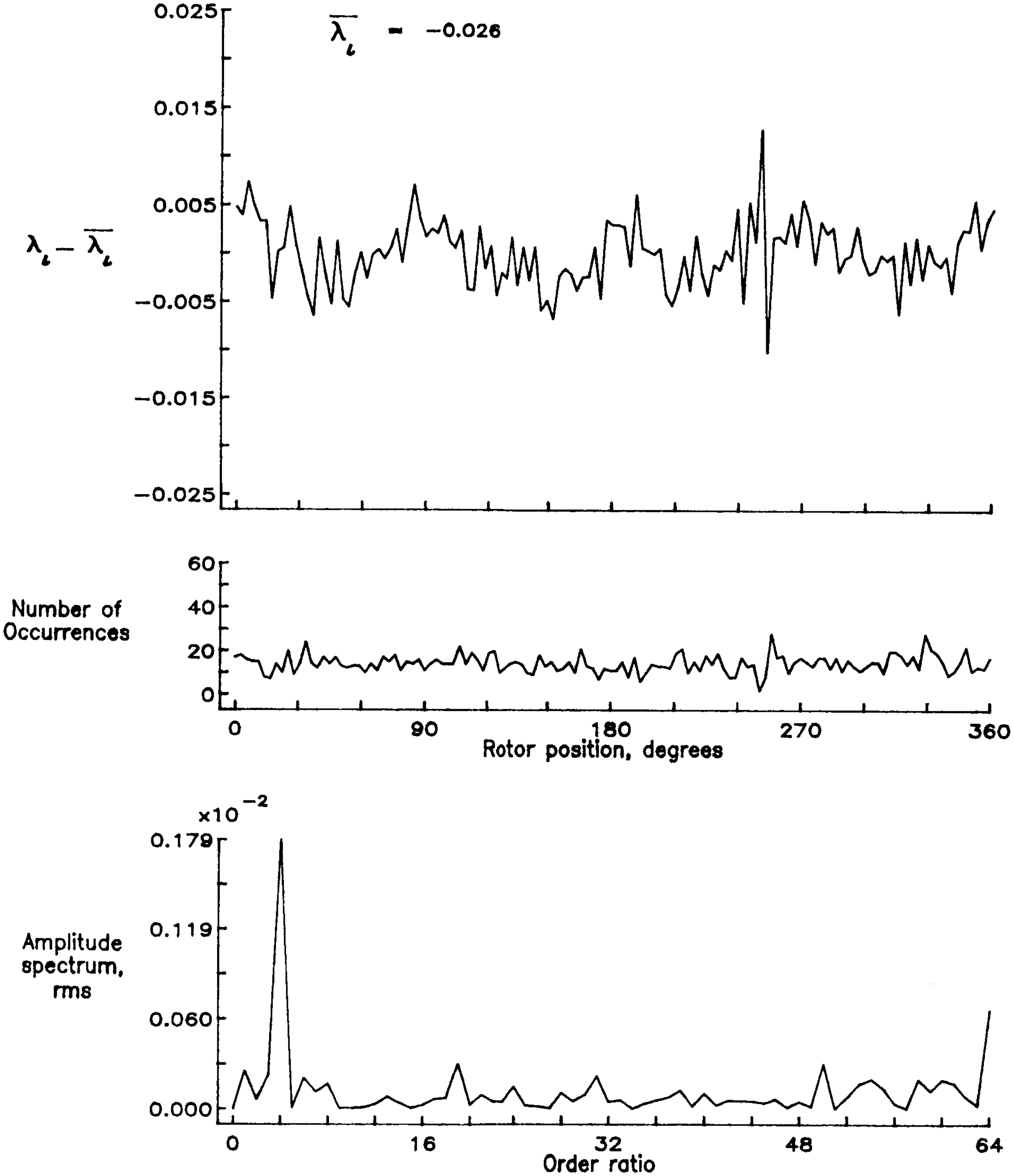


Figure 26.— Induced inflow velocity measured at 0 degrees and r/R of 1.04.



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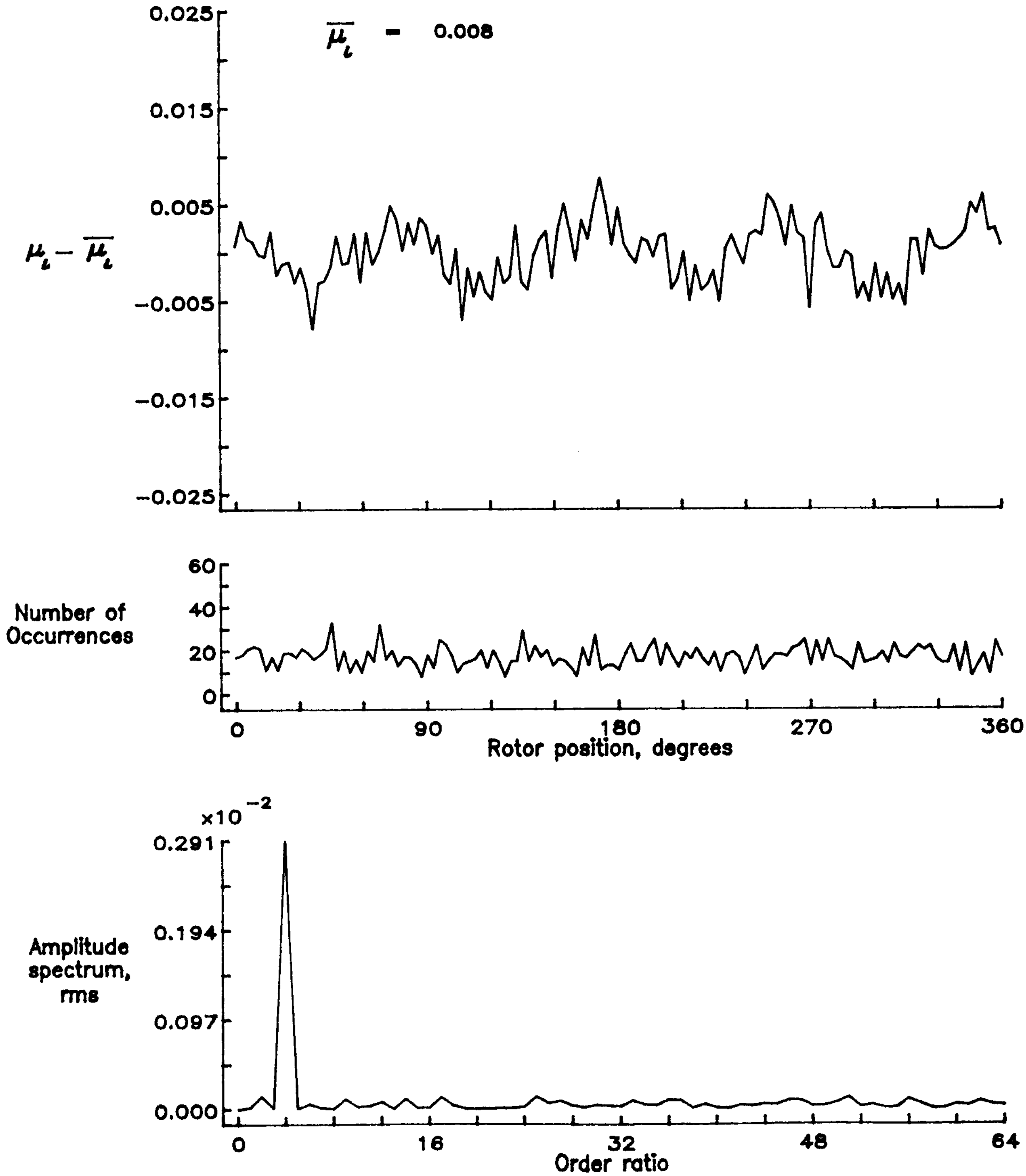
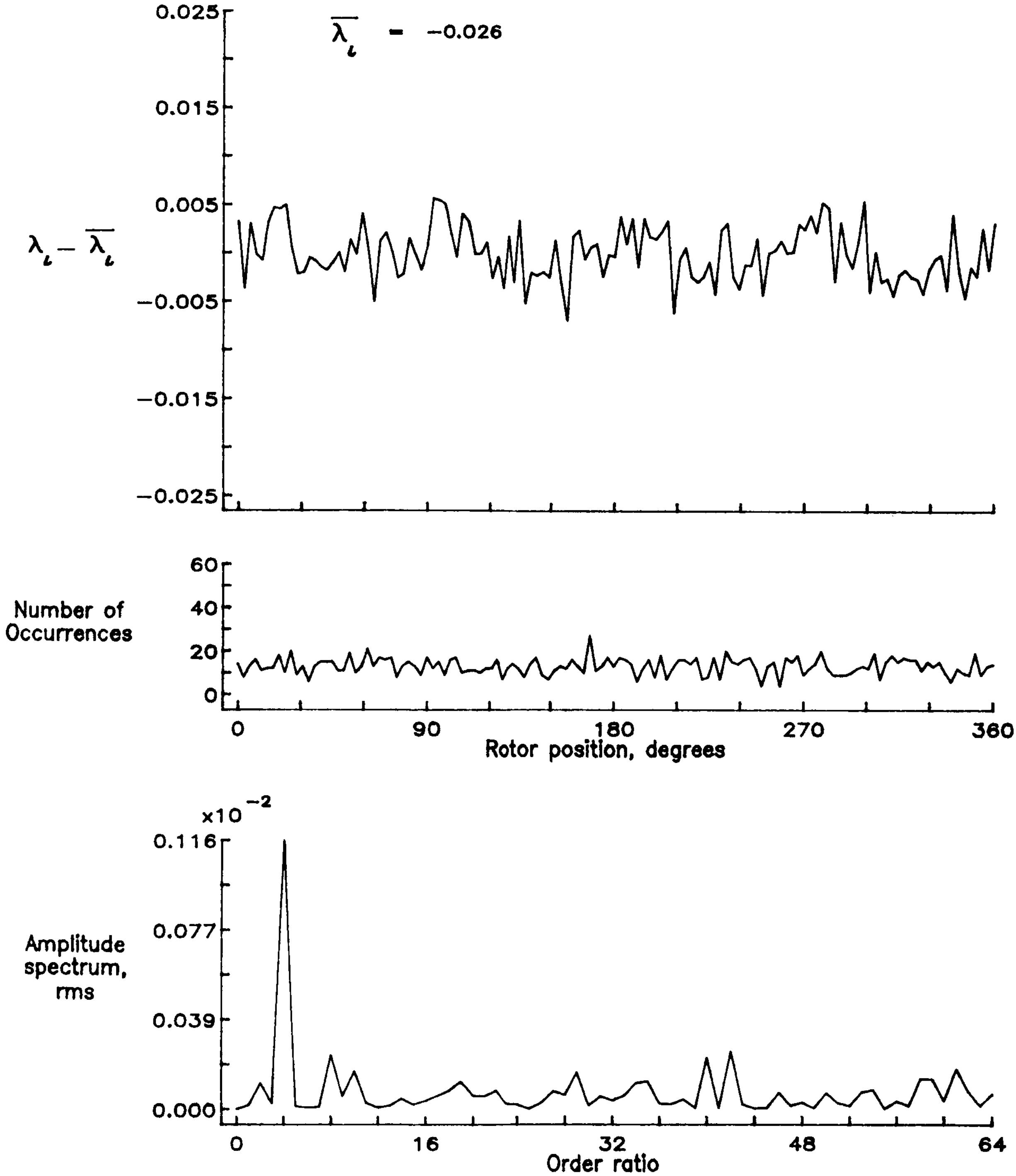


Figure 27.– Induced inflow velocity measured at 0 degrees and r/R of 1.10.



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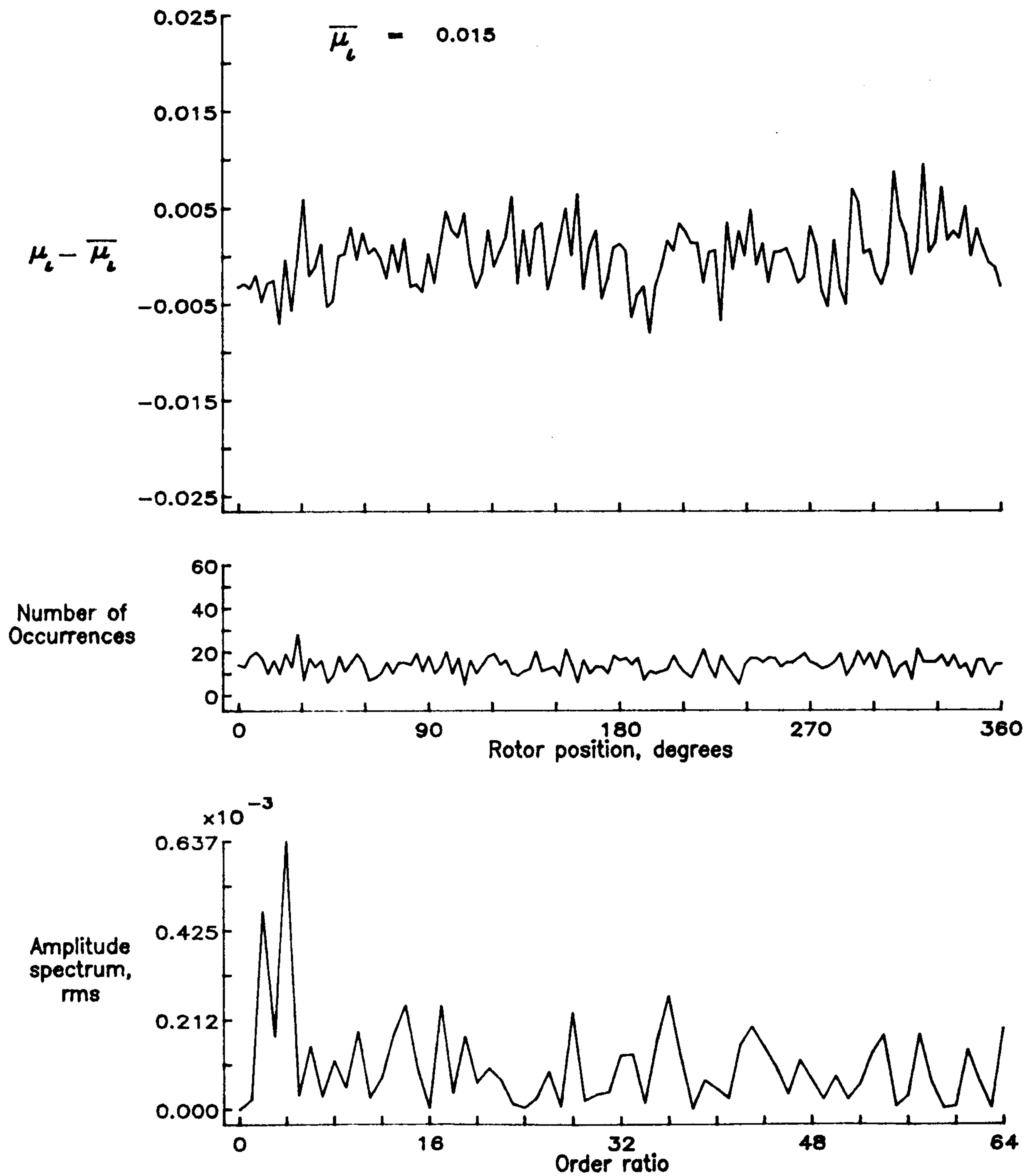
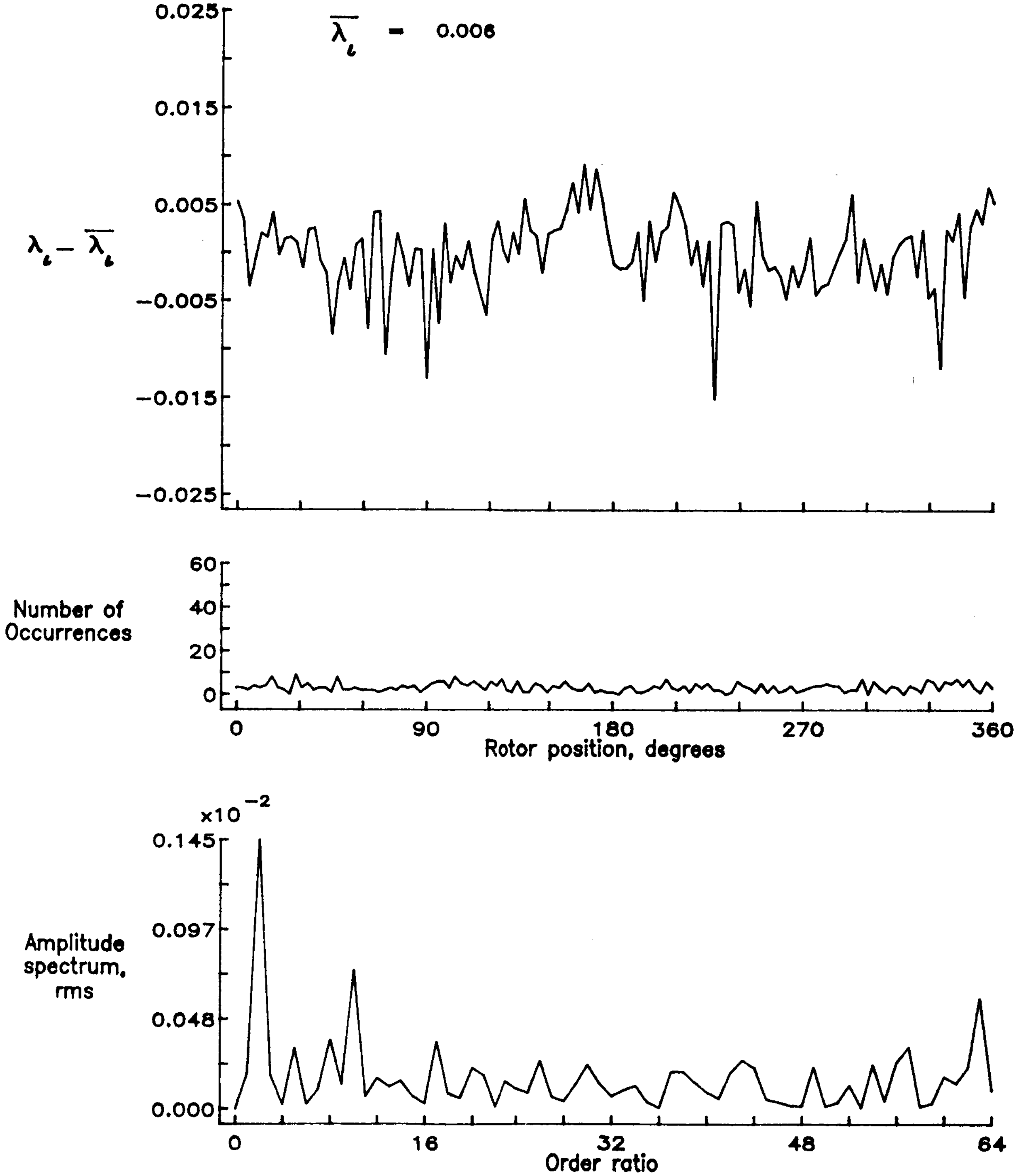


Figure 28.– Induced inflow velocity measured at 30 degrees and r/R of 0.20.



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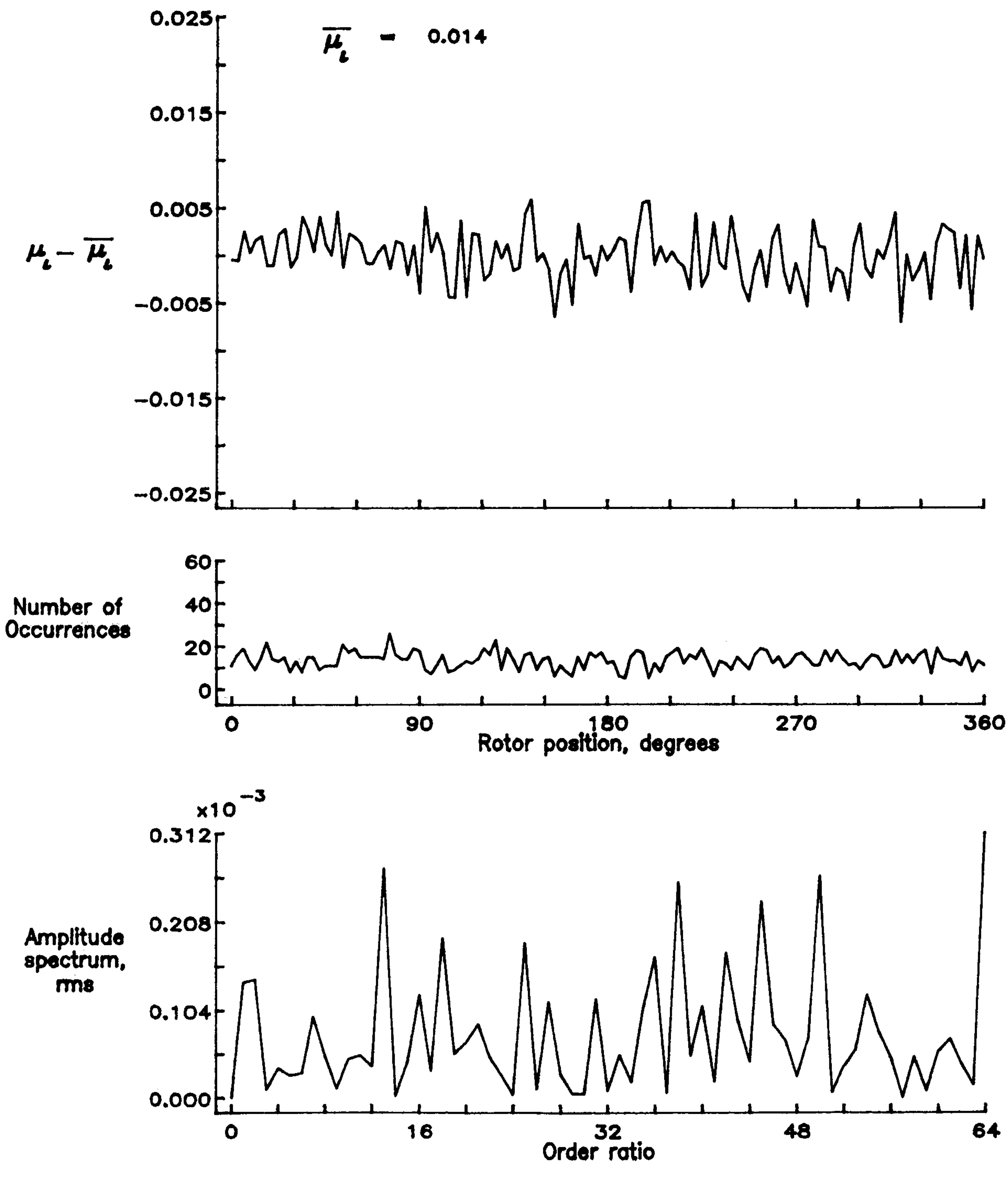
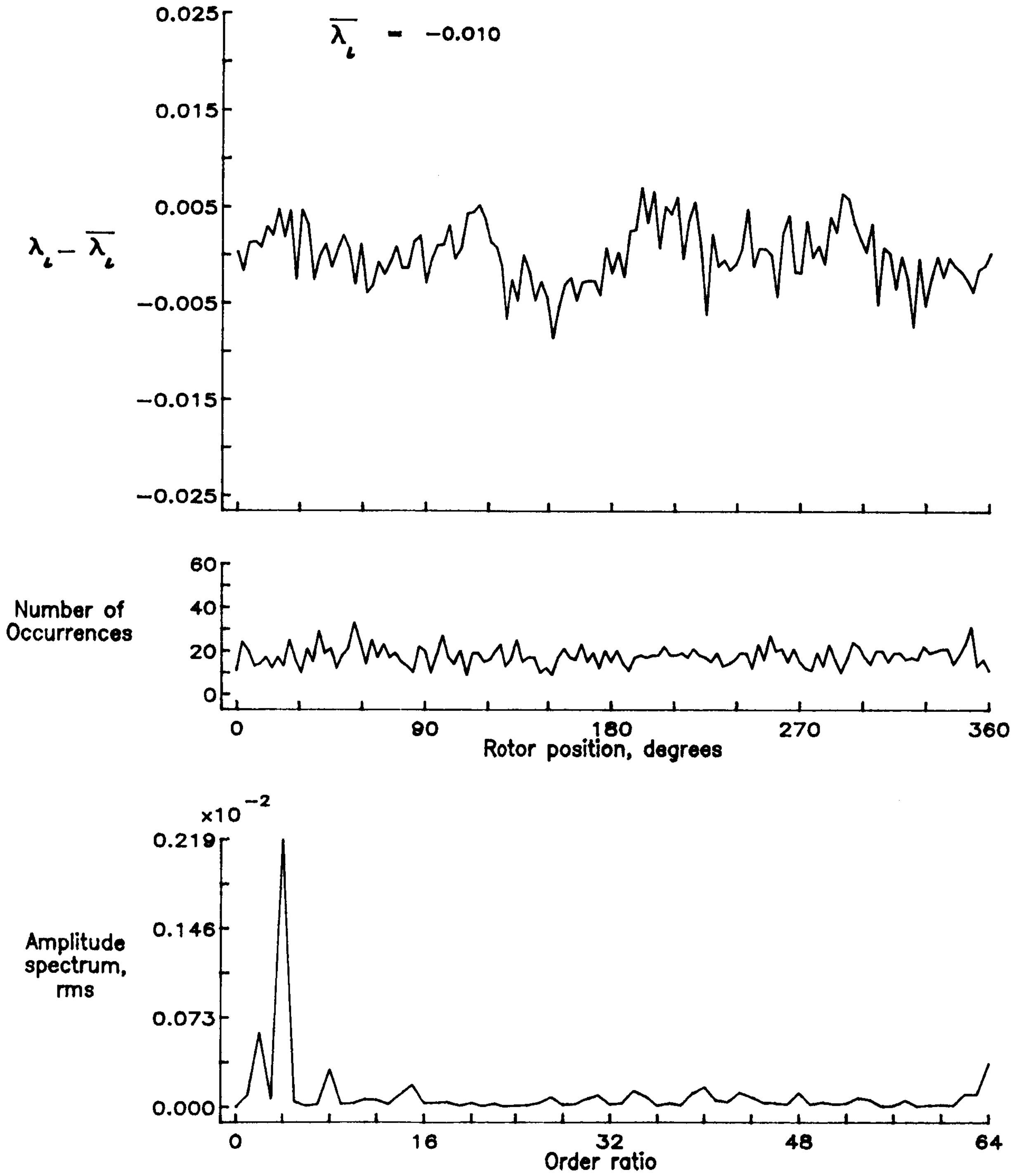


Figure 29.– Induced inflow velocity measured at 30 degrees and r/R of 0.40.



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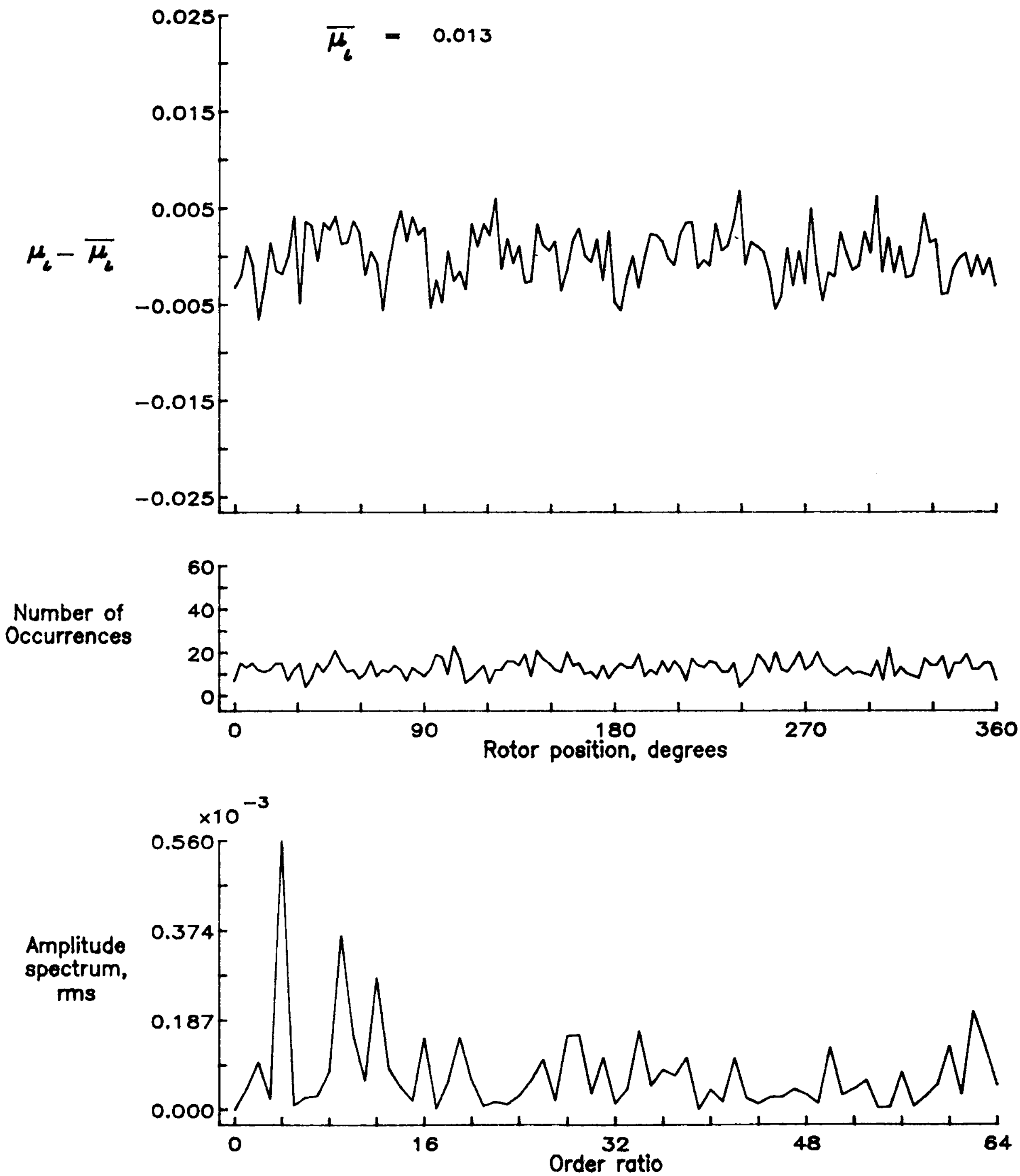


Figure 30.– Induced inflow velocity measured at 30 degrees and r/R of 0.50.

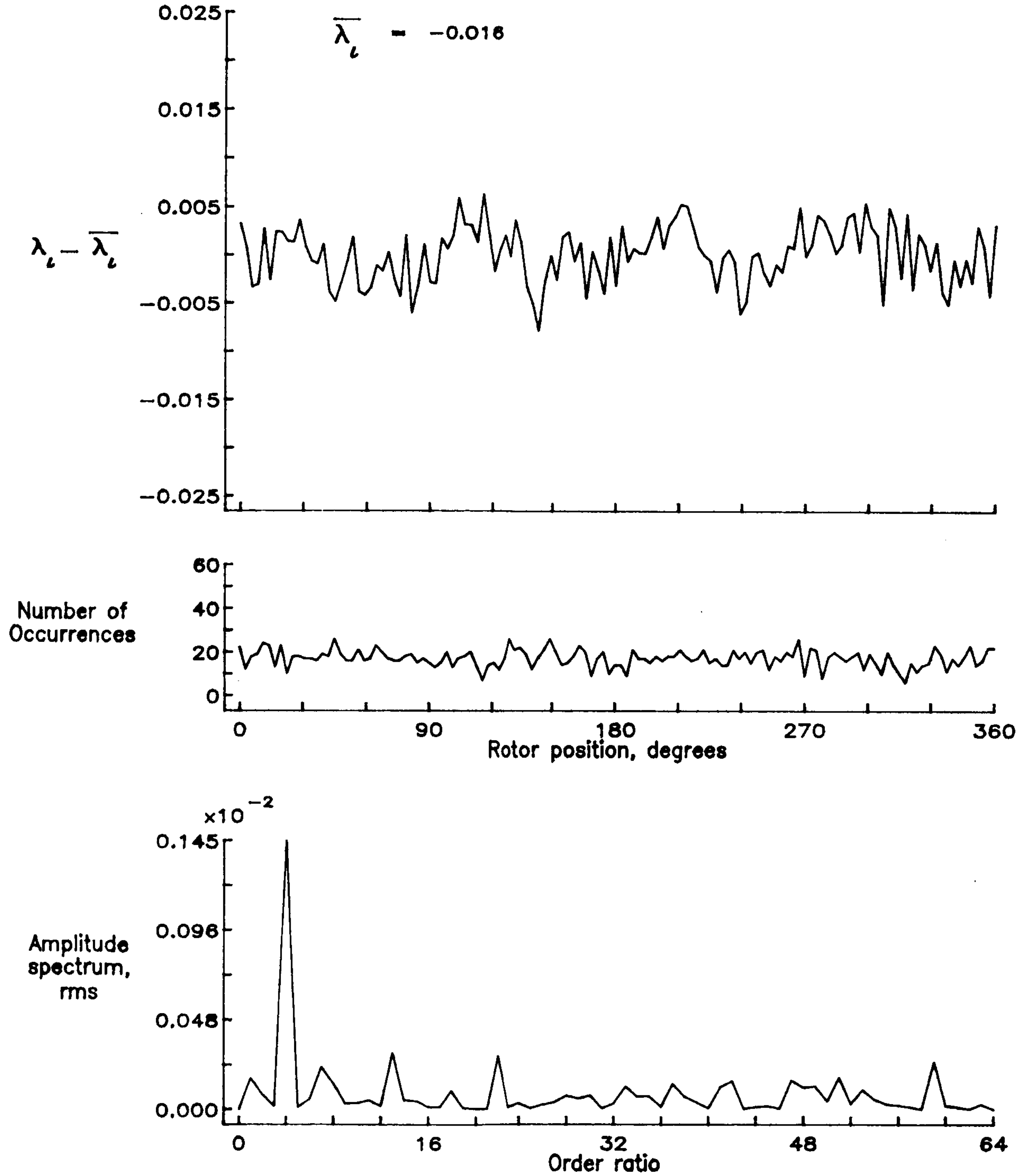


Figure 30.– Concluded.

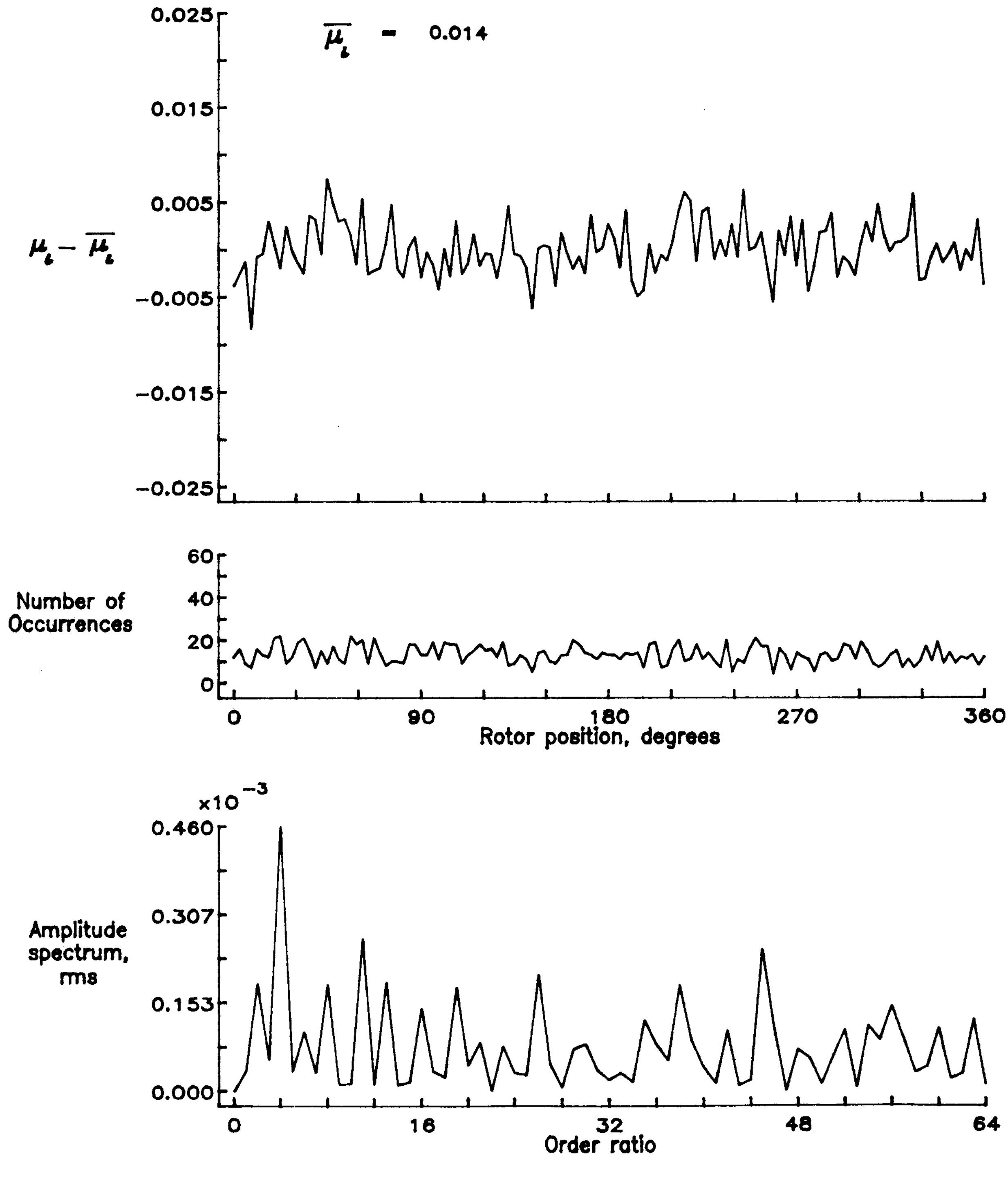


Figure 31.– Induced inflow velocity measured at 30 degrees and r/R of 0.60.

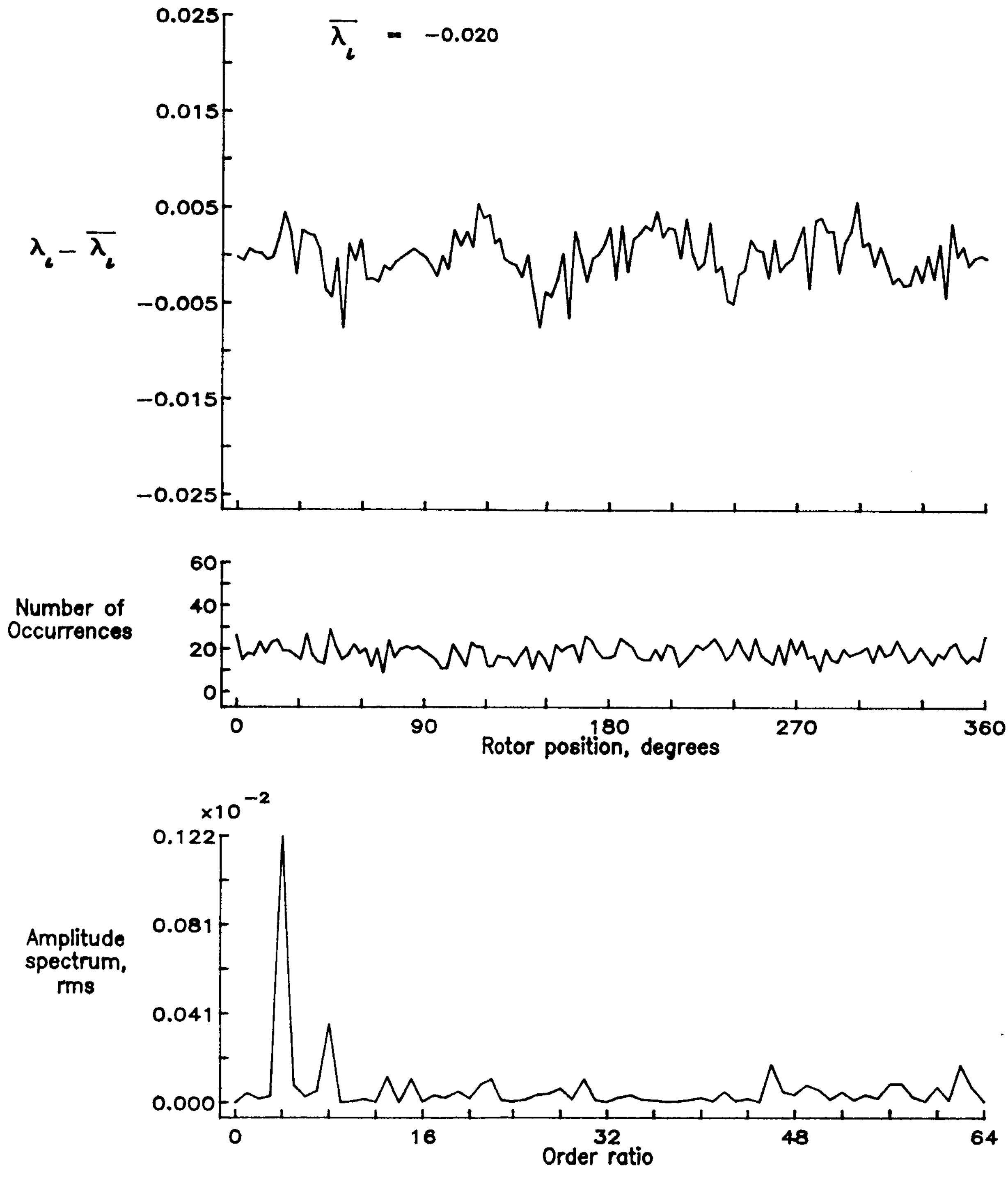


Figure 31.– Concluded.

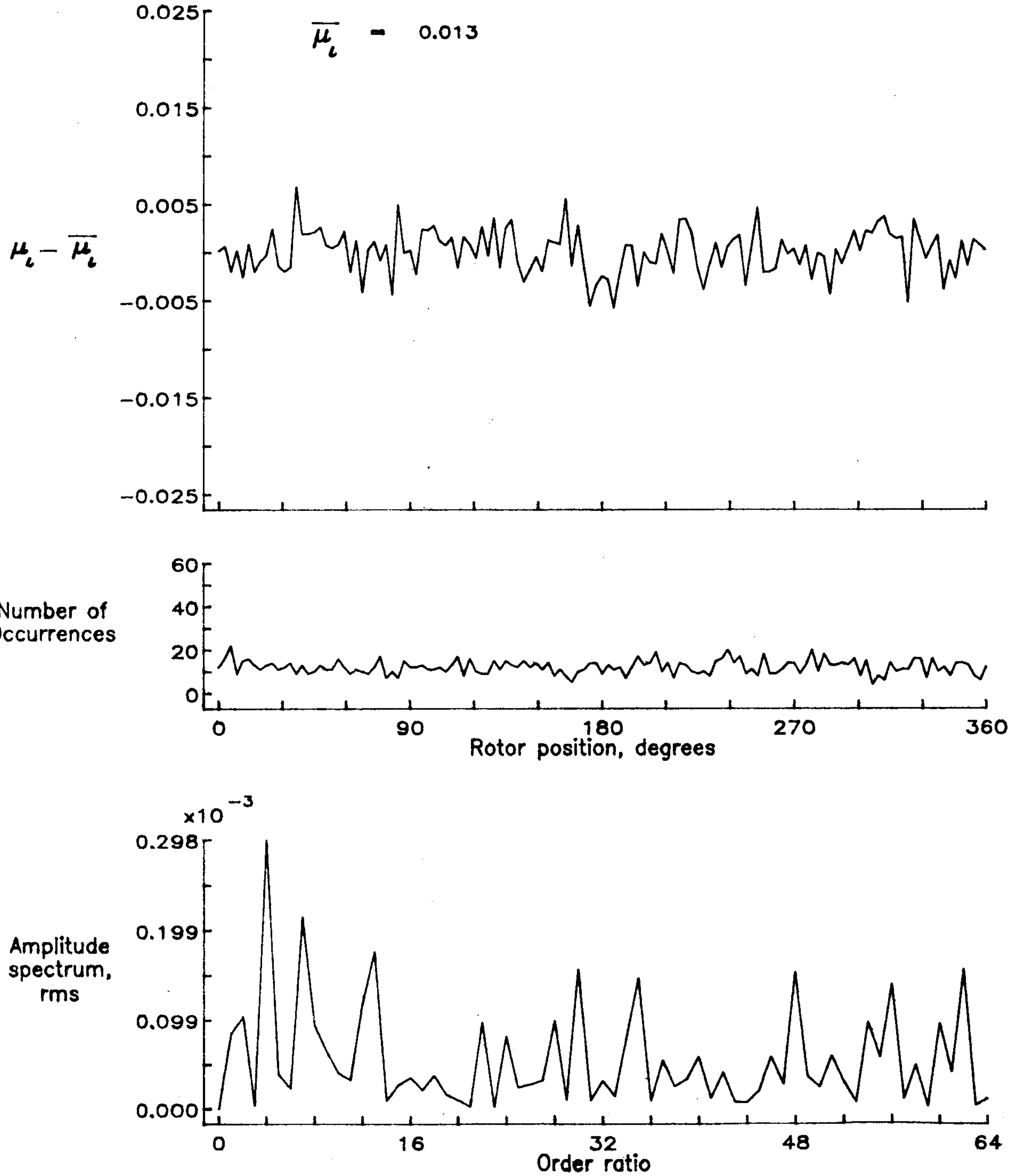
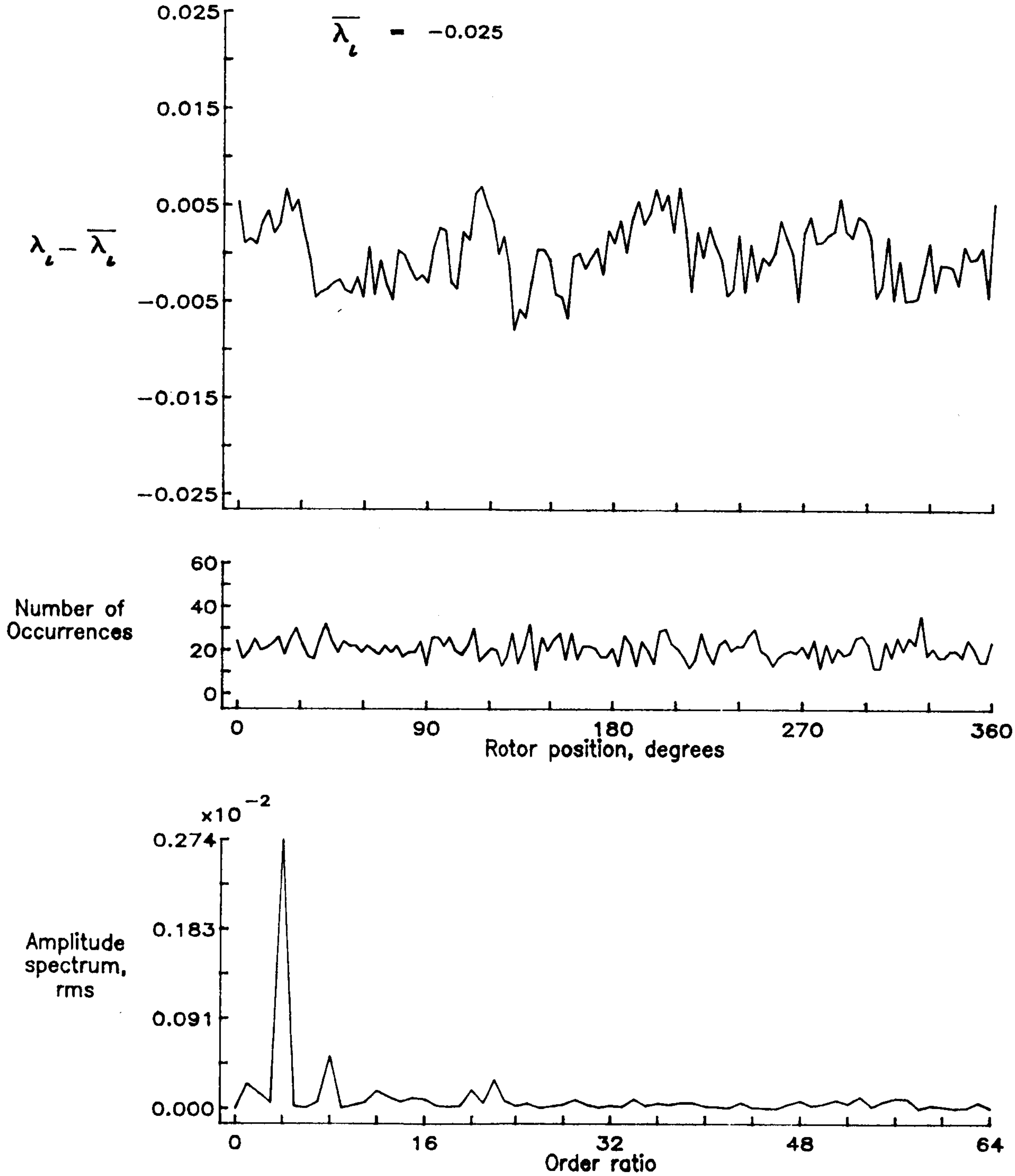


Figure 32.– Induced inflow velocity measured at 30 degrees and r/R of 0.70.



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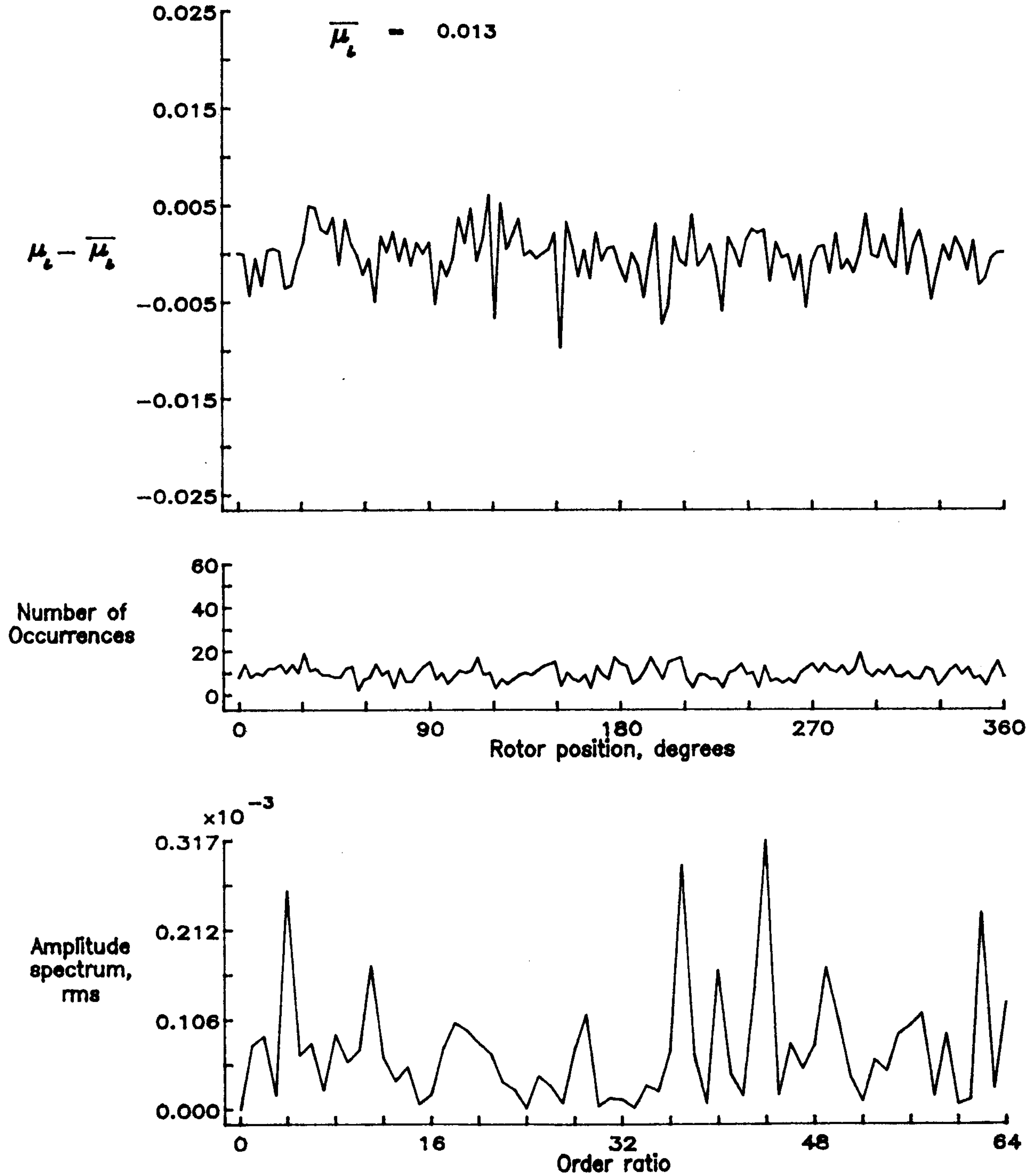
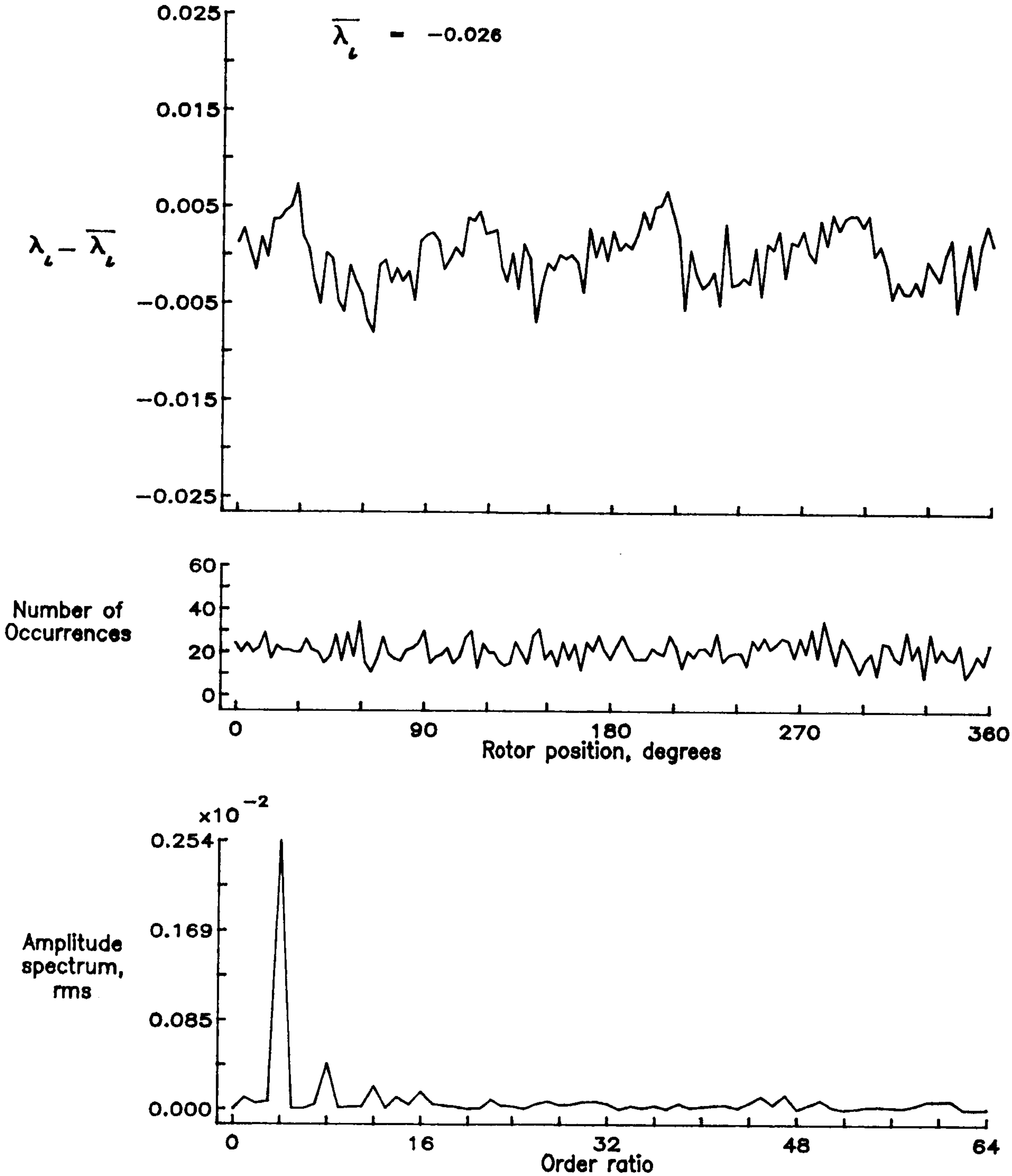


Figure 33.– Induced inflow velocity measured at 30 degrees and r/R of 0.74.



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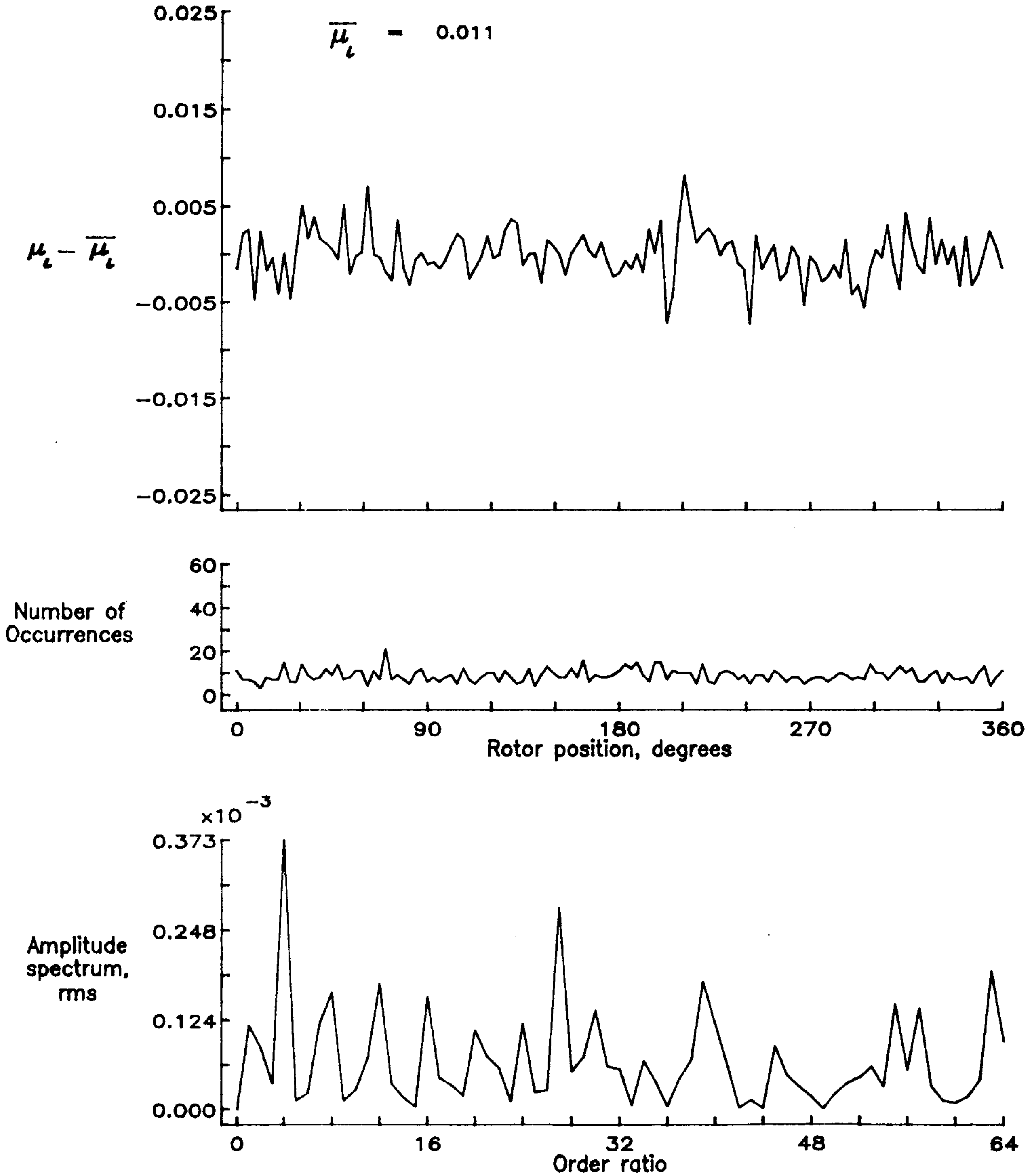
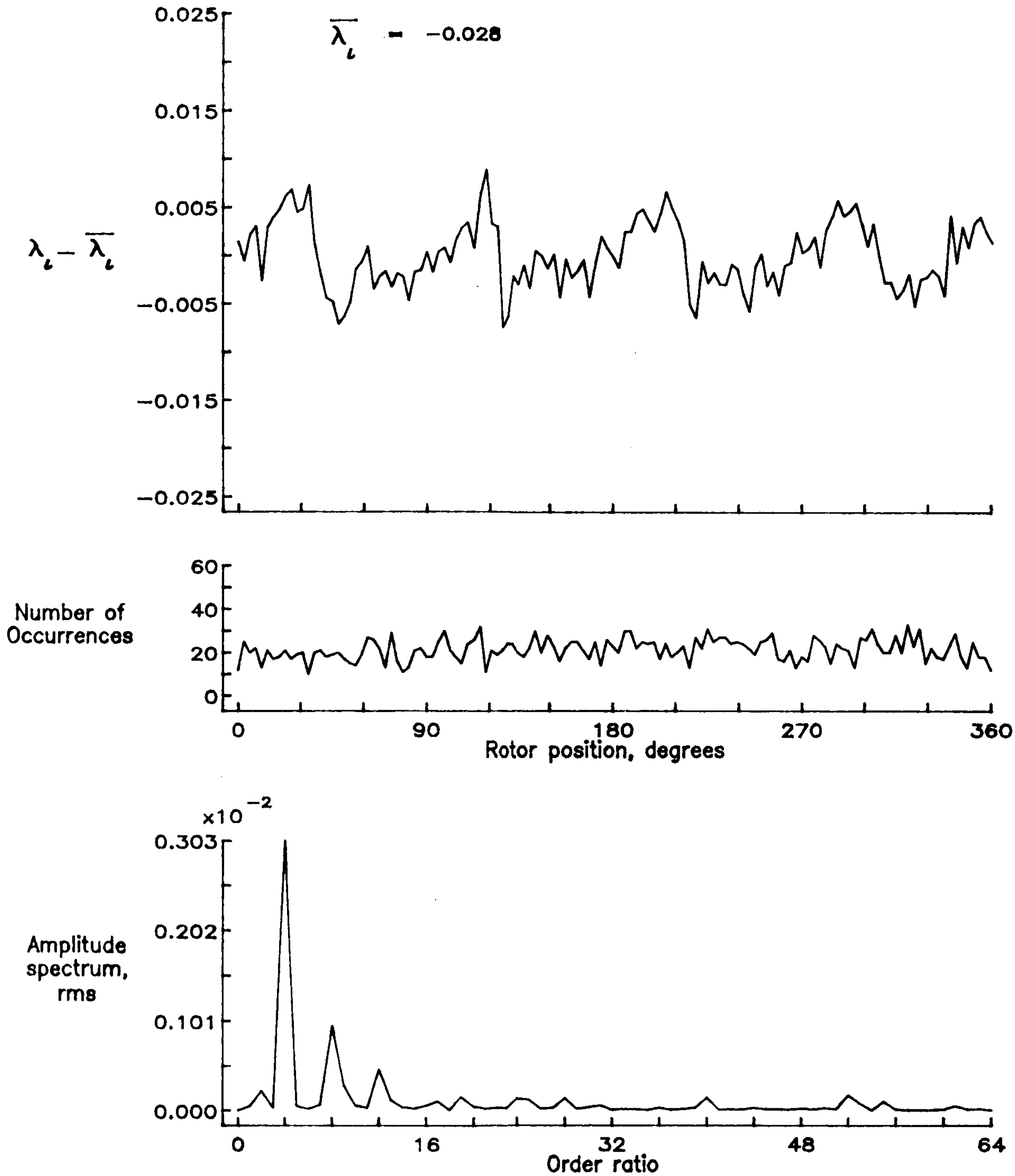


Figure 34.– Induced inflow velocity measured at 30 degrees and r/R of 0.78.



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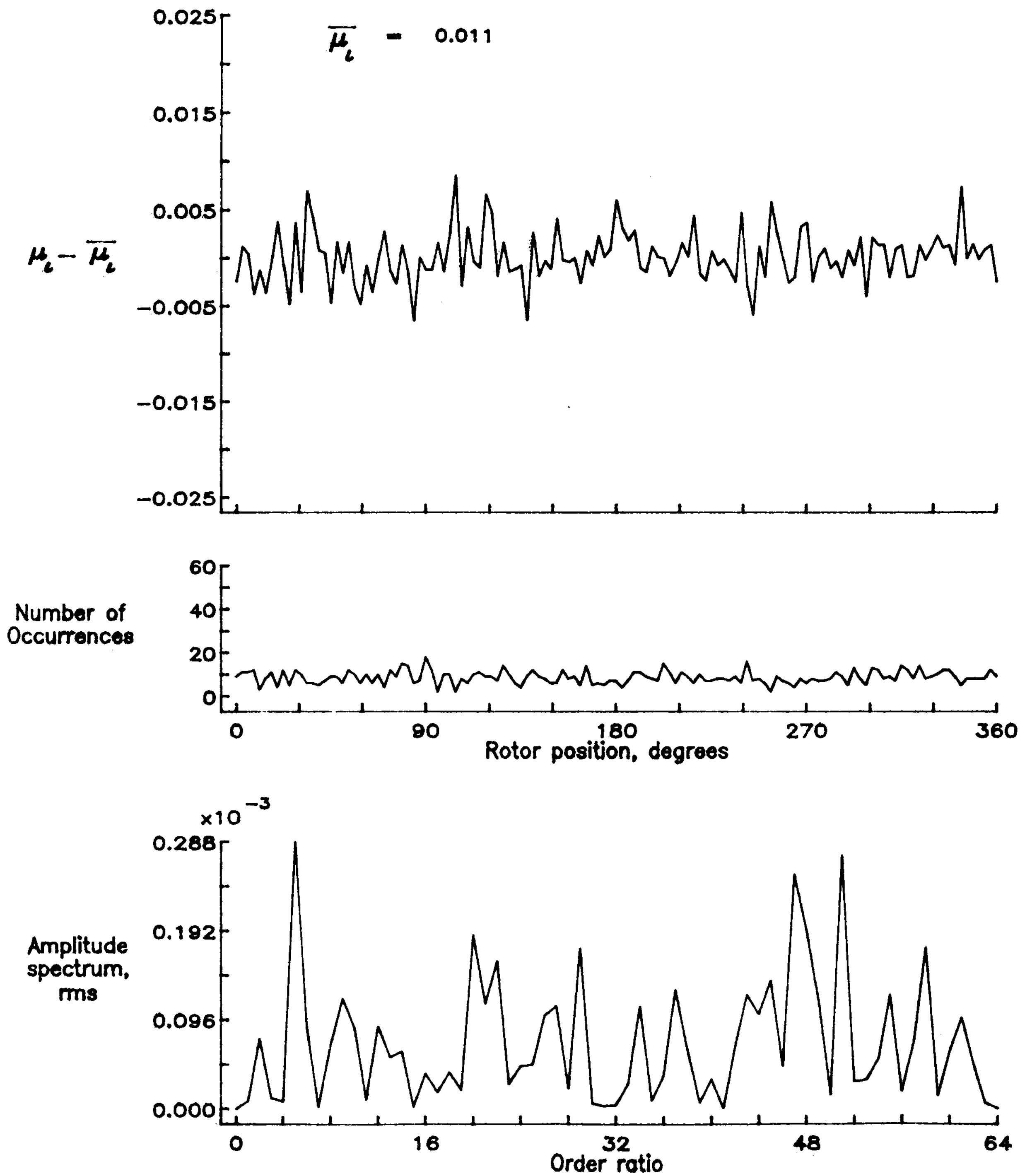
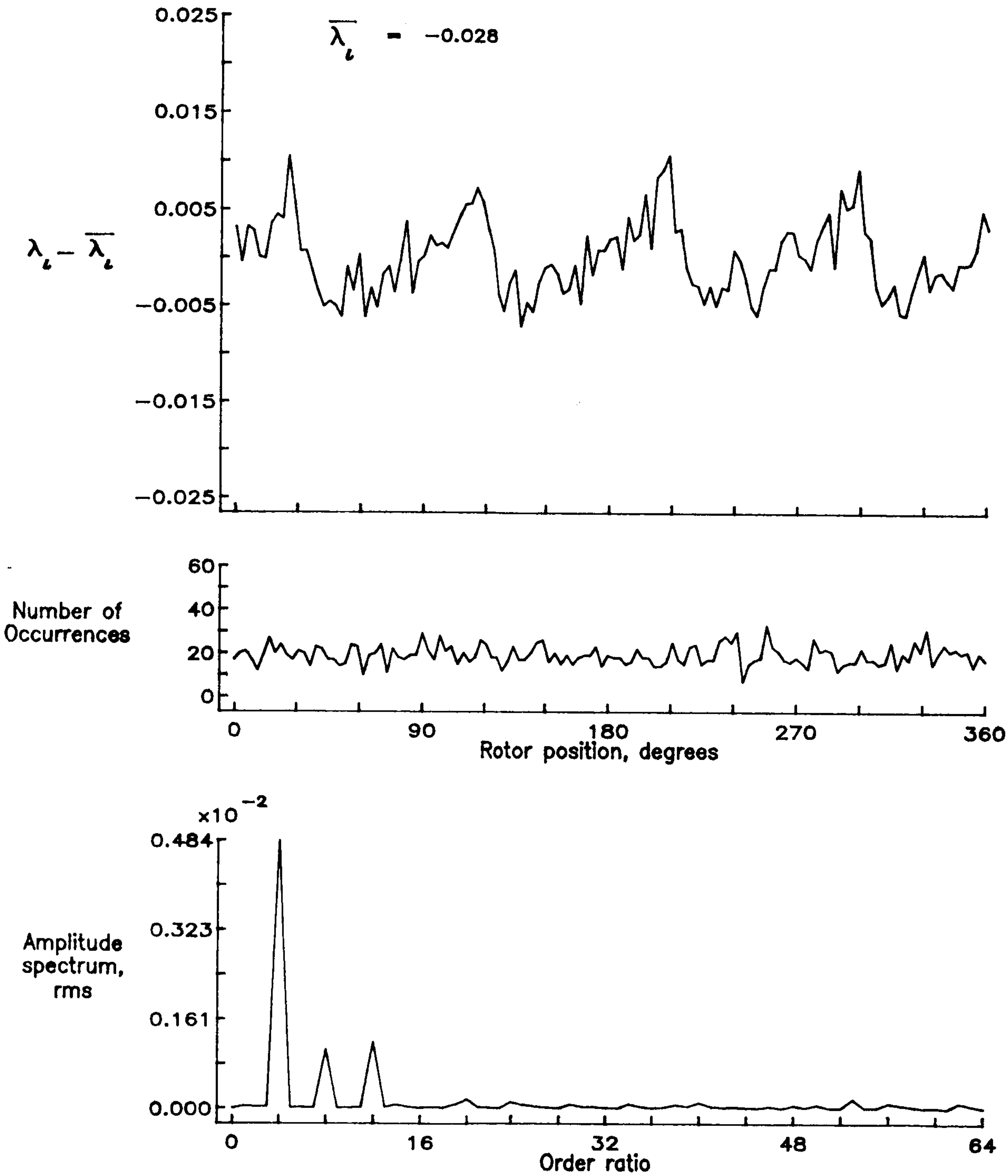


Figure 35.– Induced inflow velocity measured at 30 degrees and r/R of 0.82.



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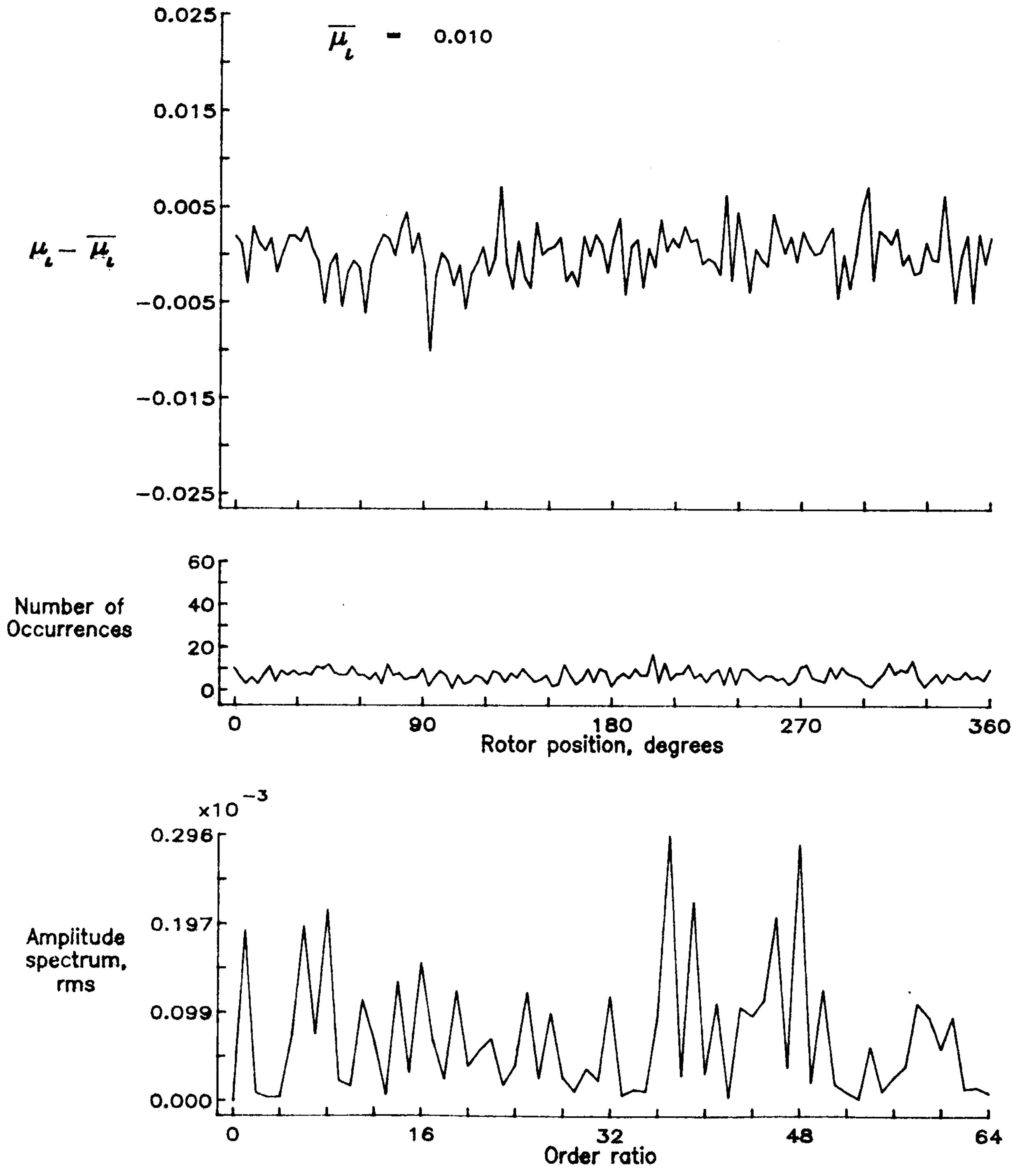
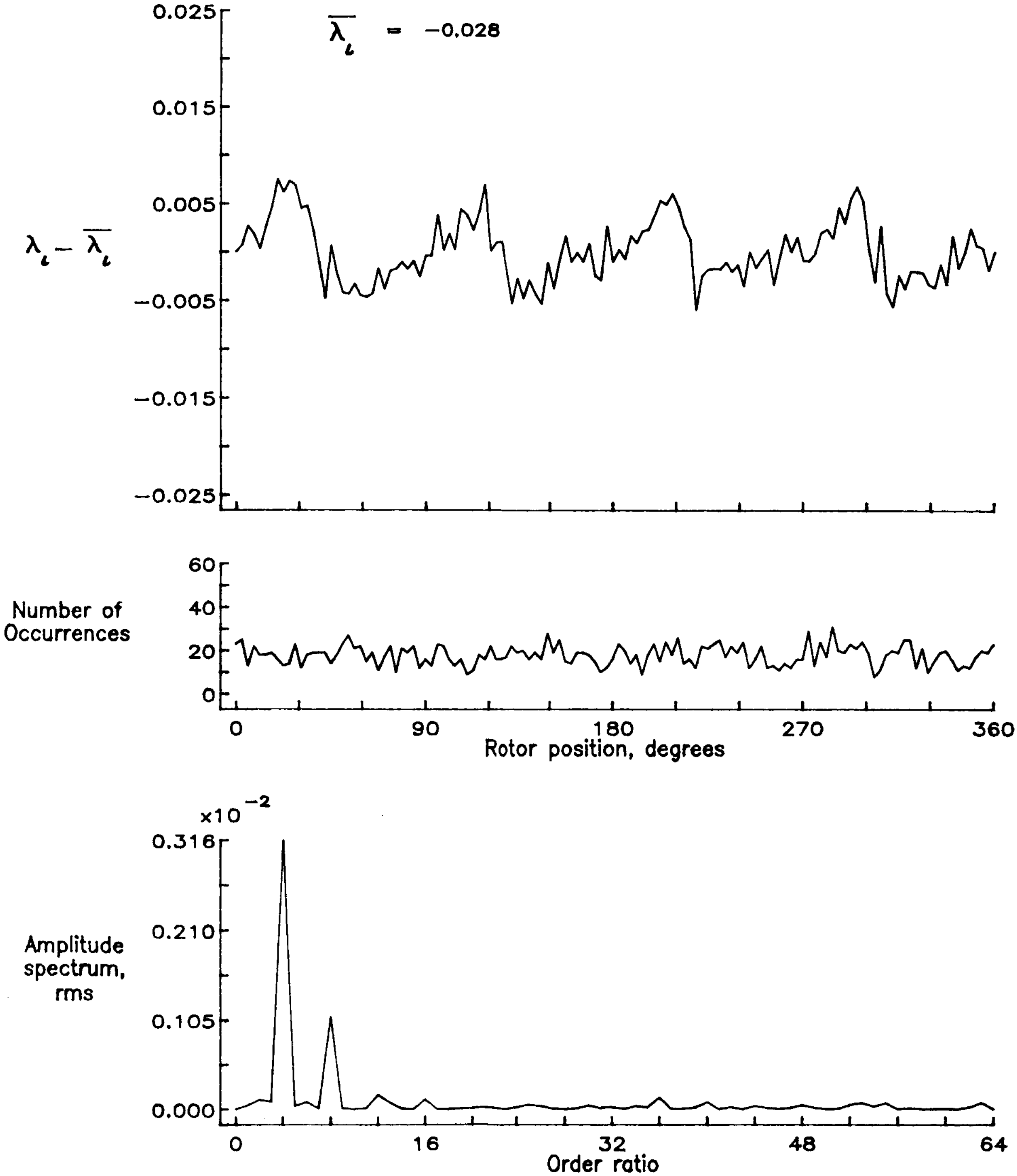


Figure 36.– Induced inflow velocity measured at 30 degrees and r/R of 0.86.



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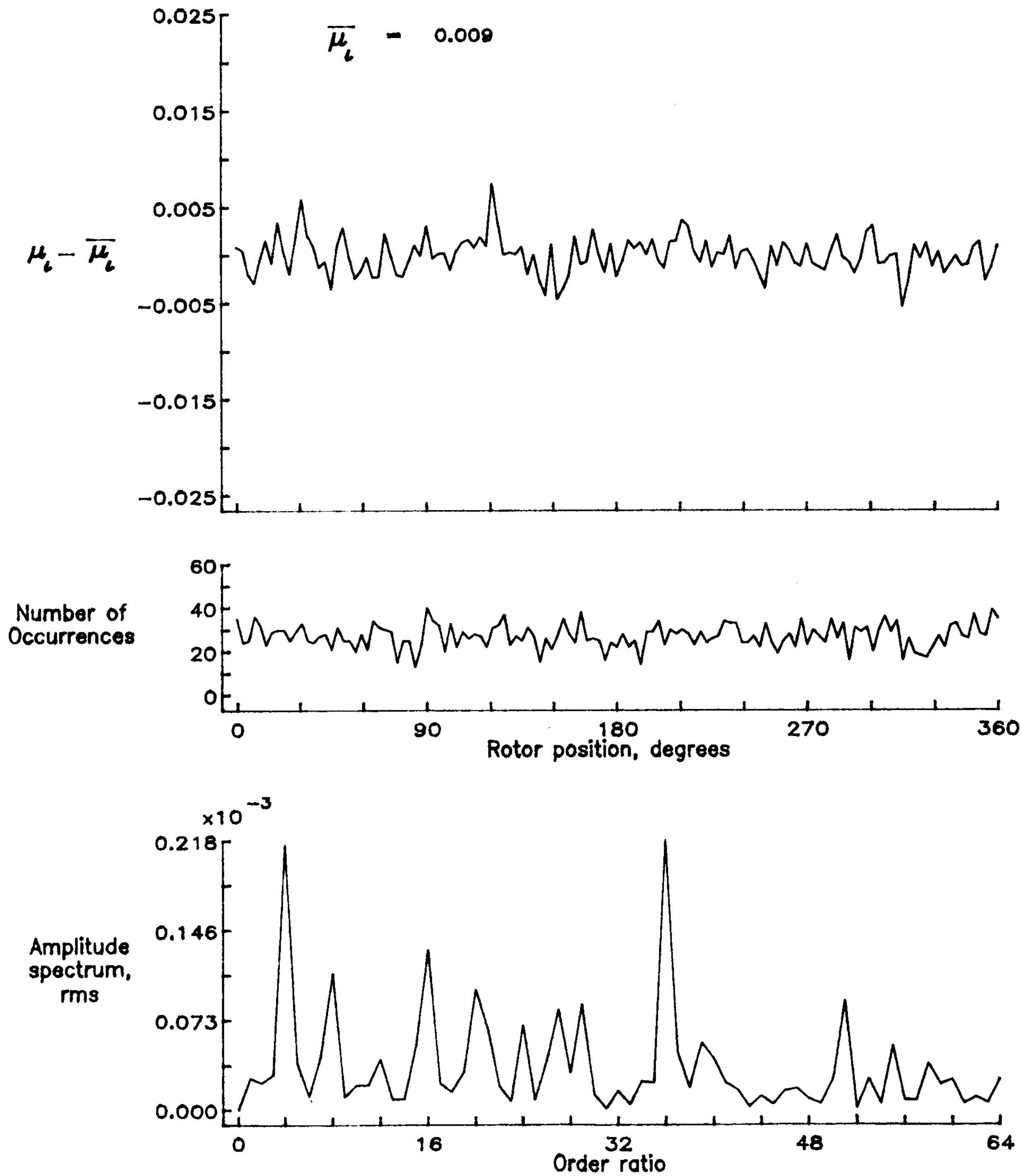
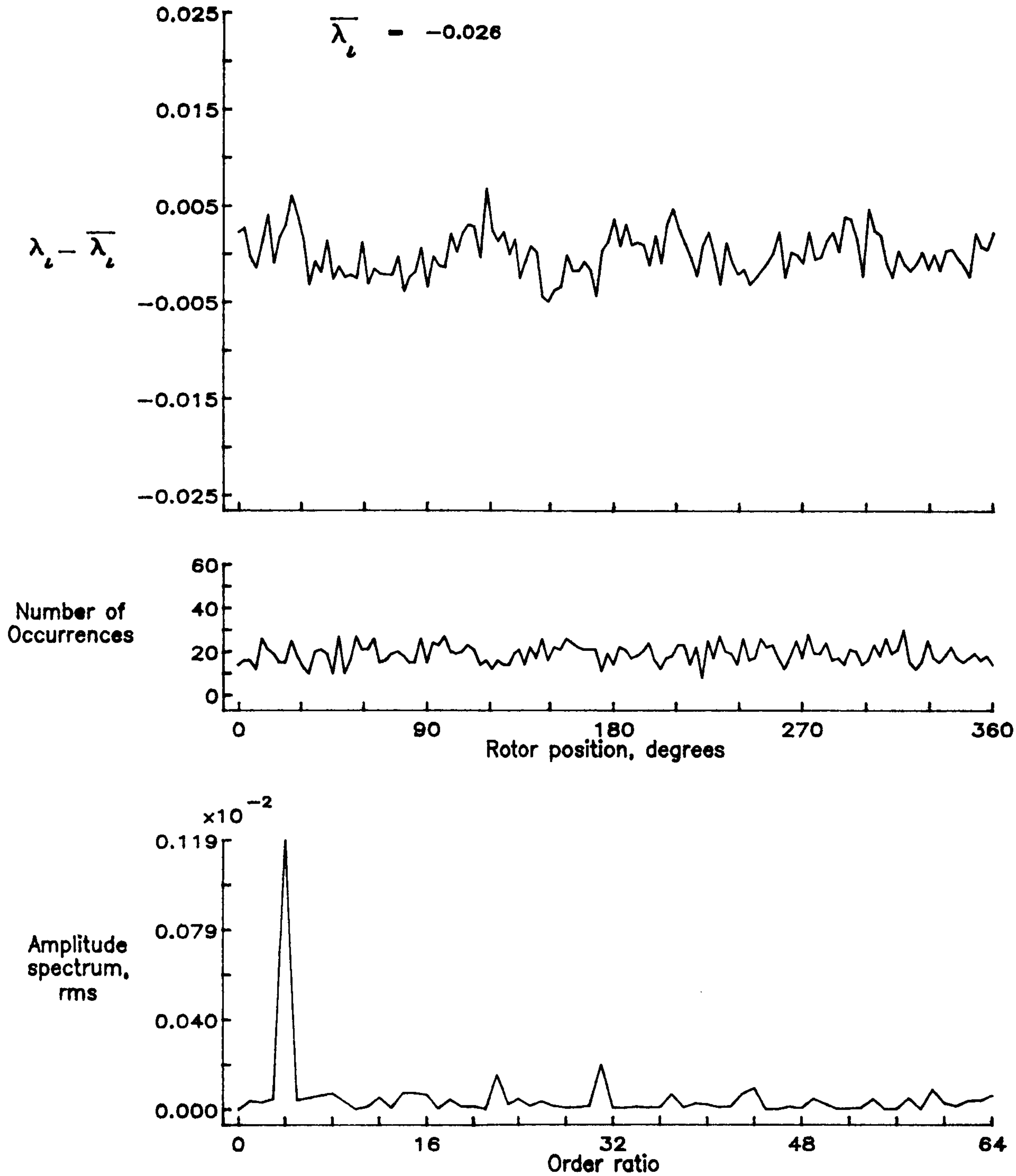


Figure 37.– Induced inflow velocity measured at 30 degrees and r/R of 0.90.



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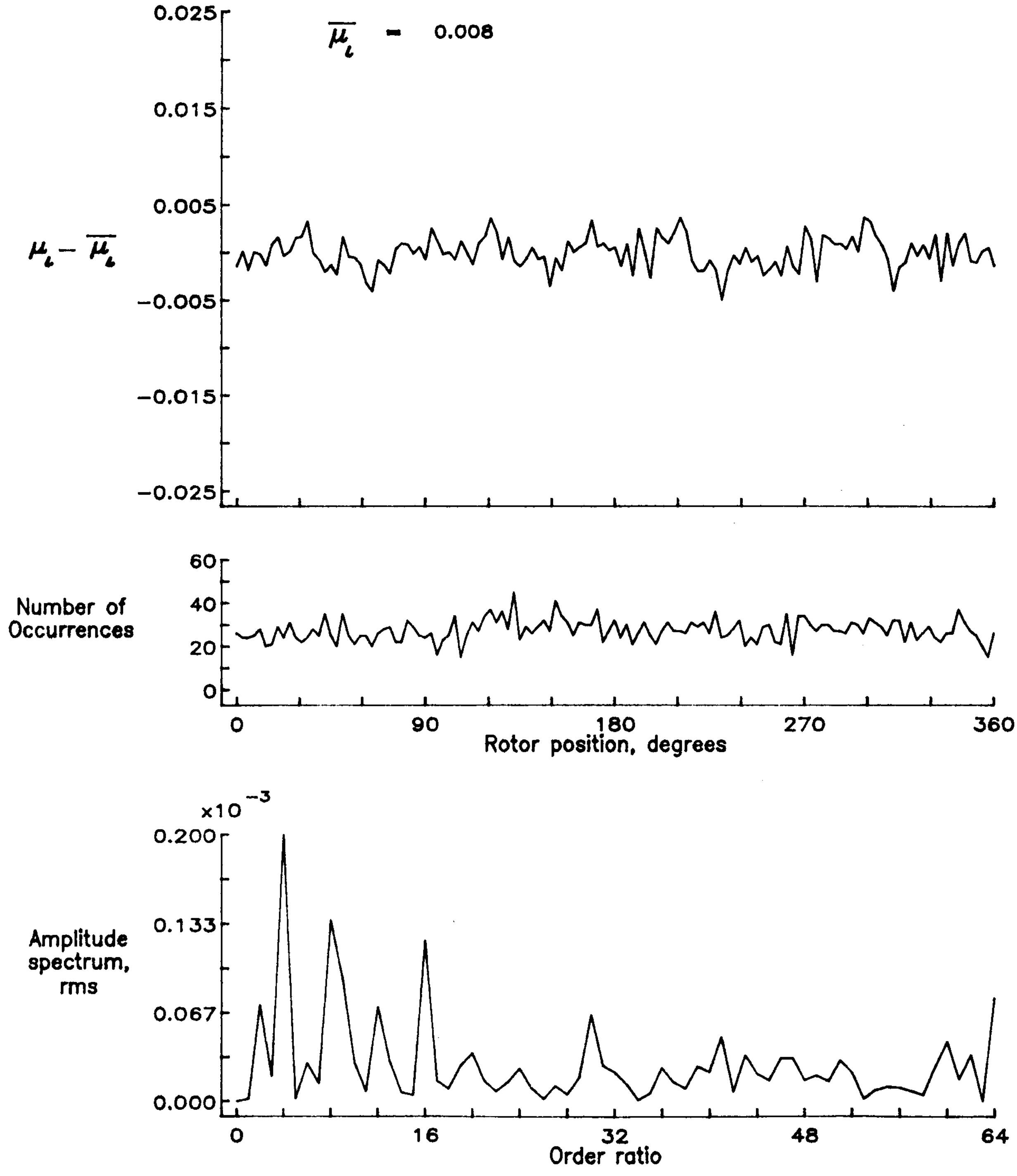
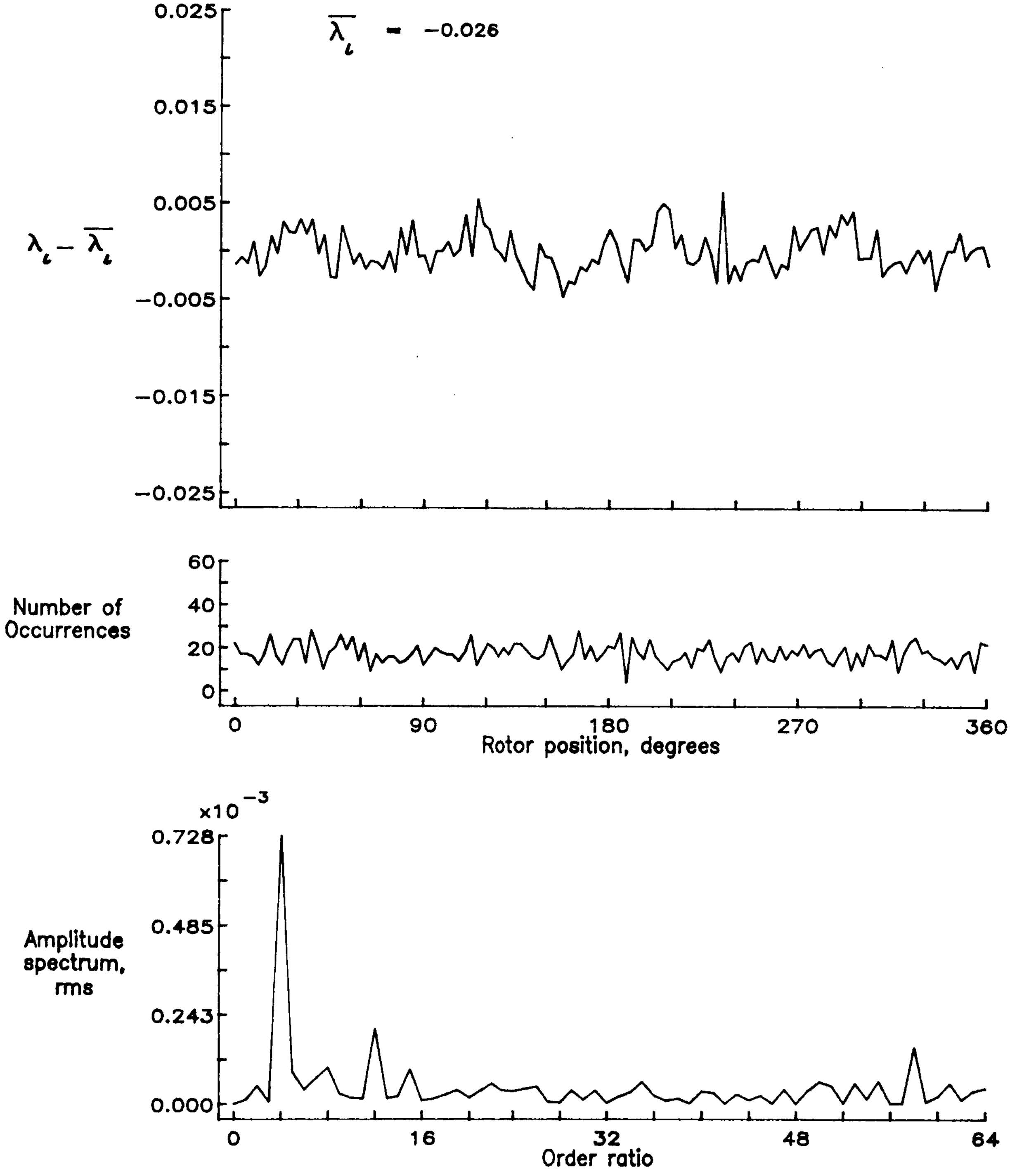


Figure 38.– Induced inflow velocity measured at 30 degrees and r/R of 0.94.



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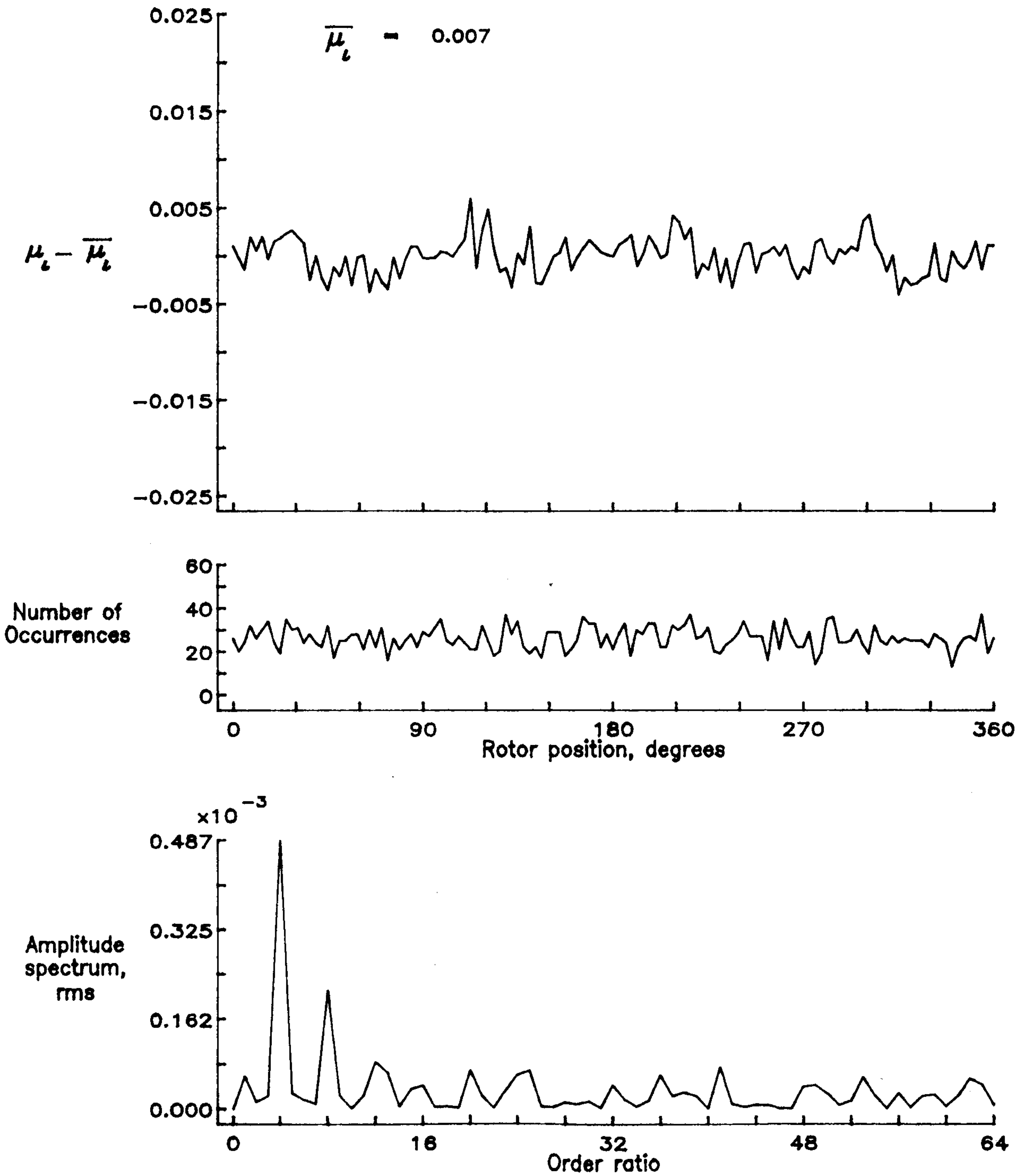


Figure 39.– Induced inflow velocity measured at 30 degrees and r/R of 0.98.

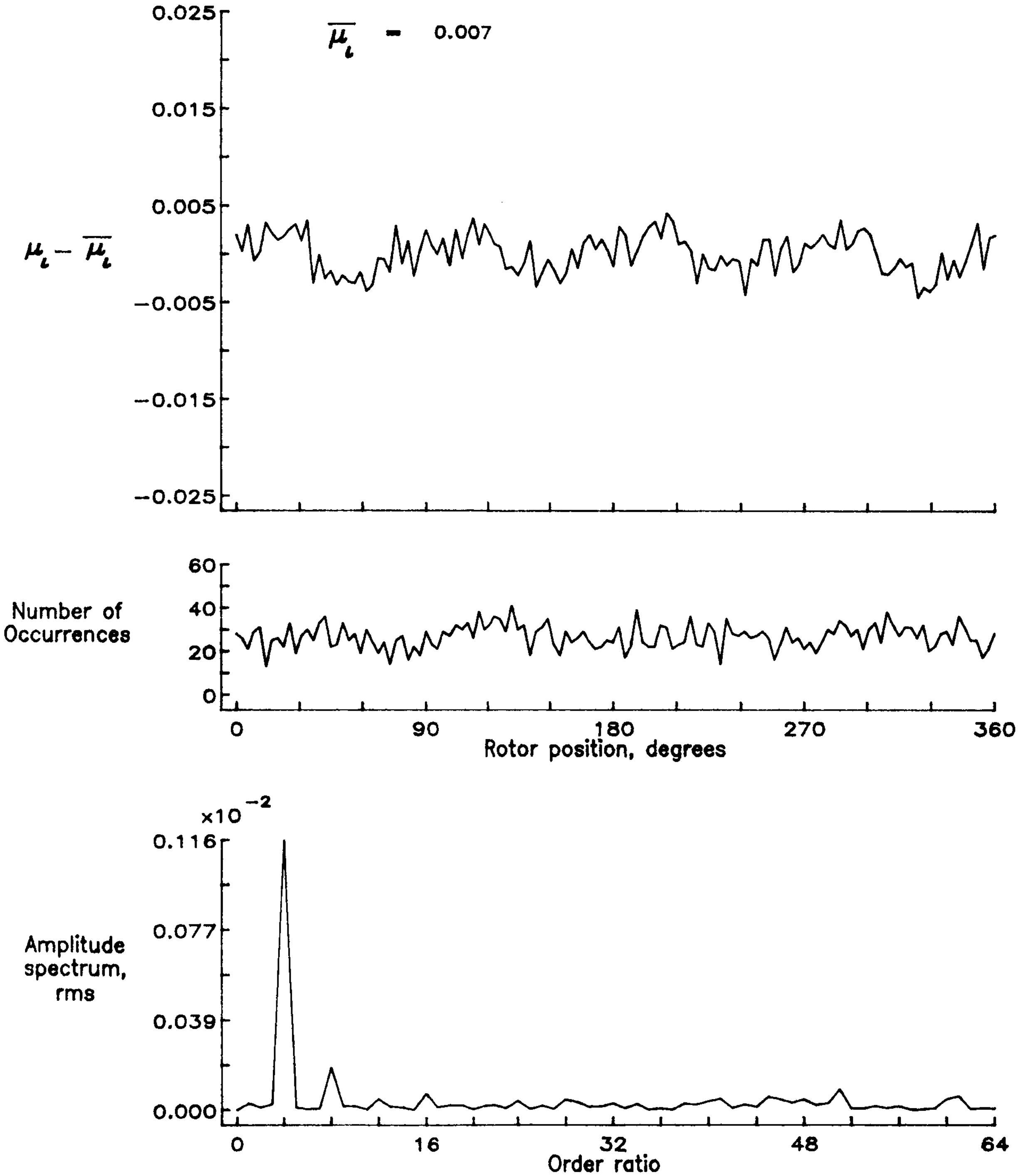
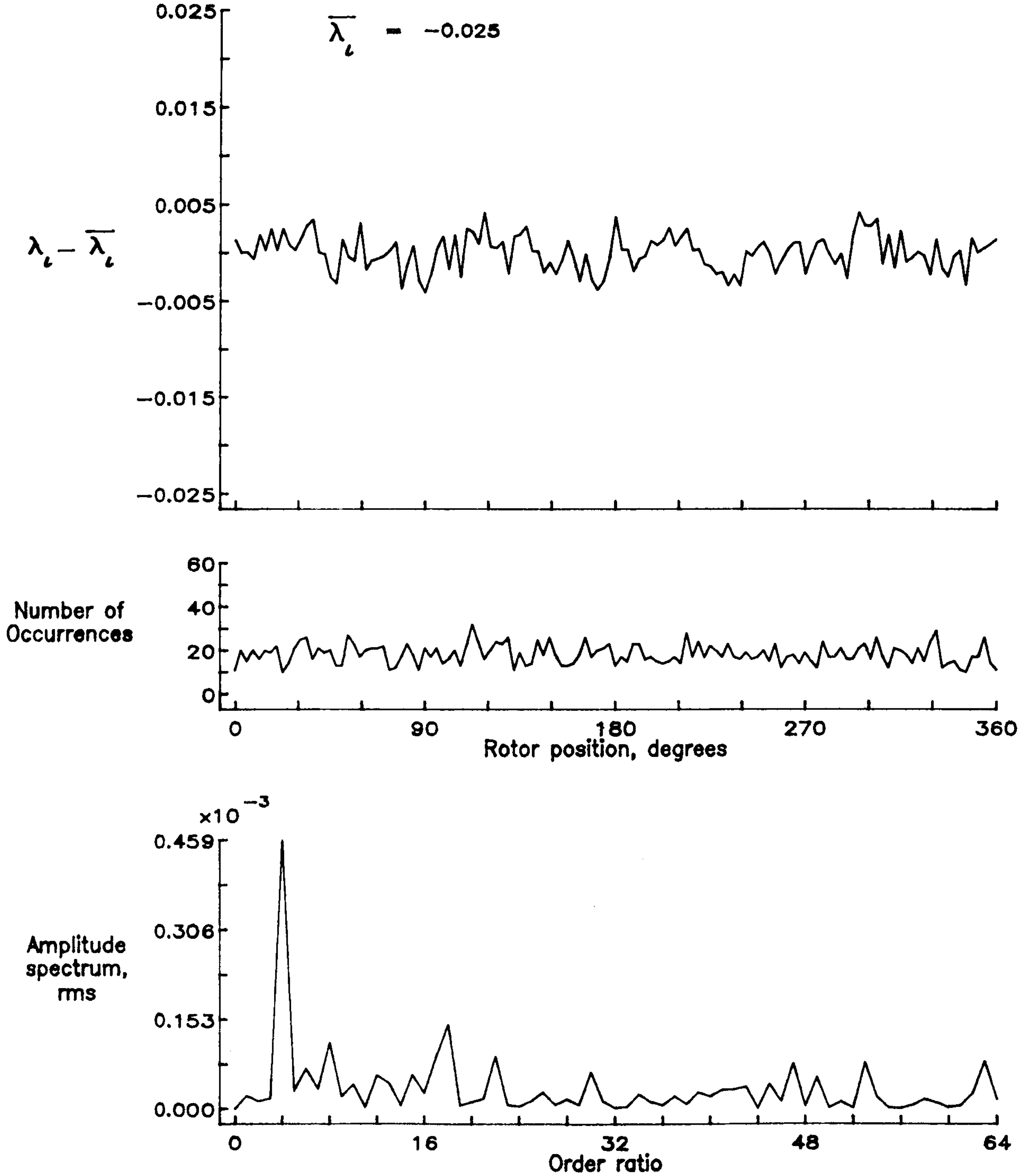


Figure 40.– Induced inflow velocity measured at 30 degrees and r/R of 1.02.



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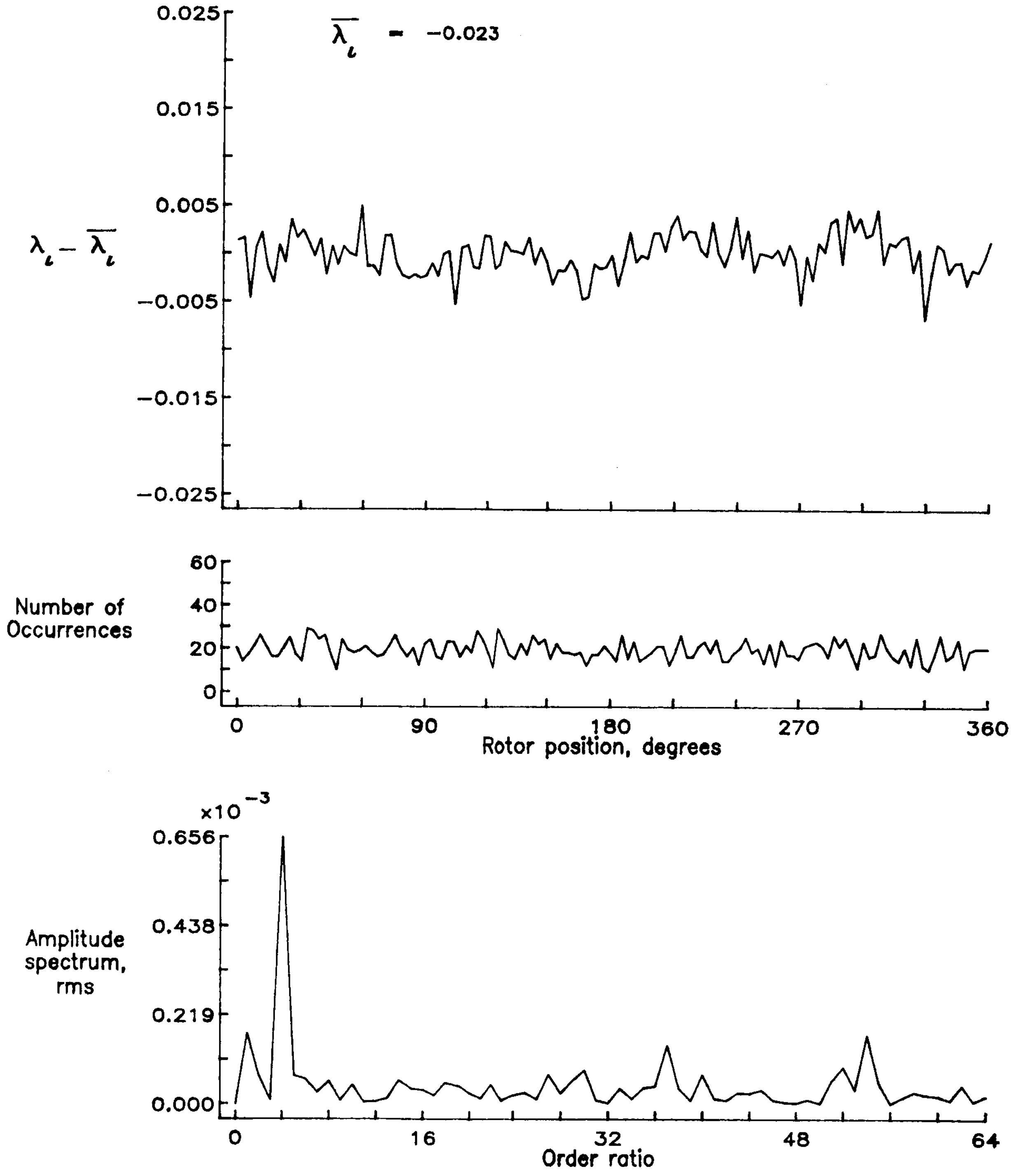

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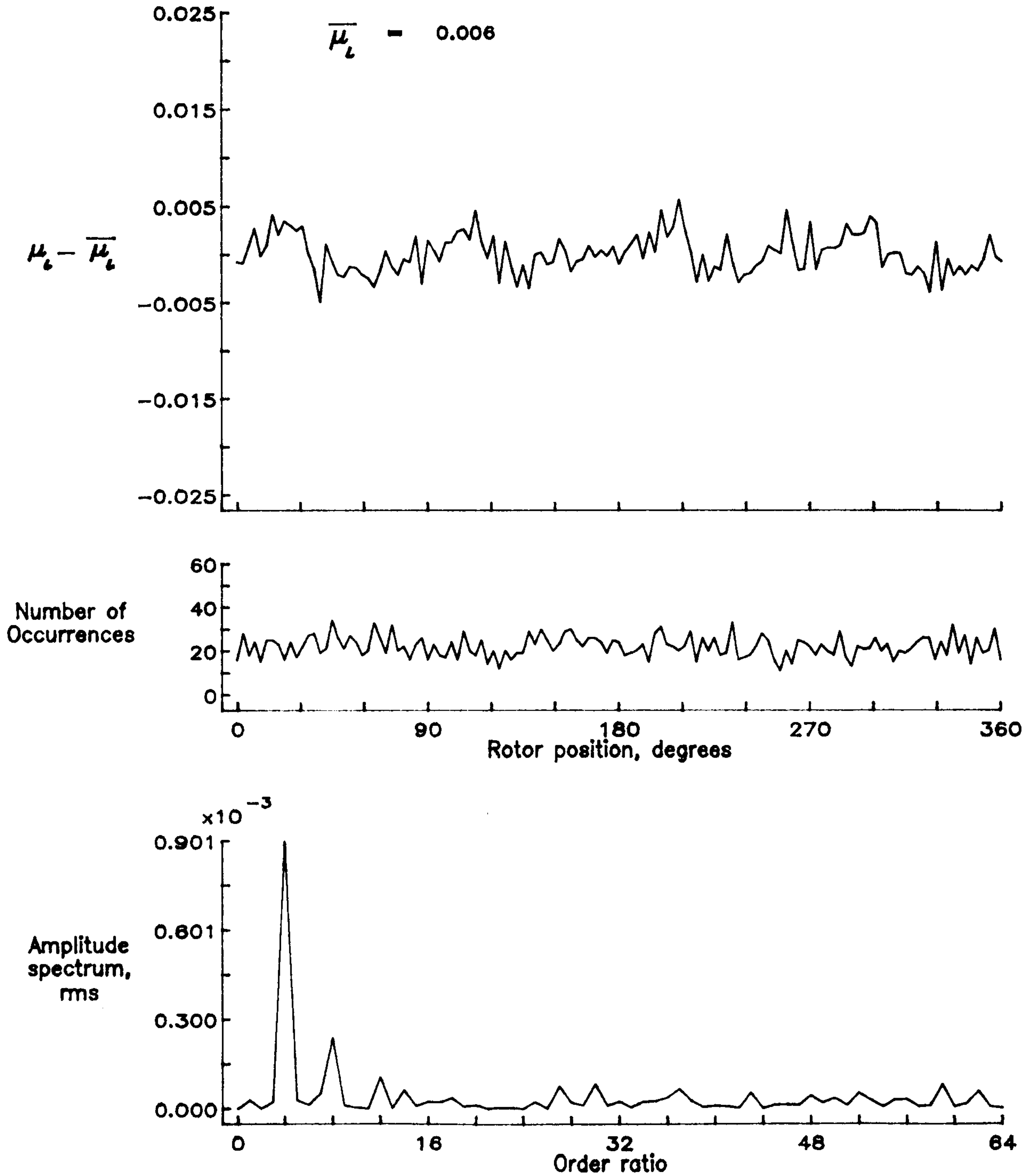
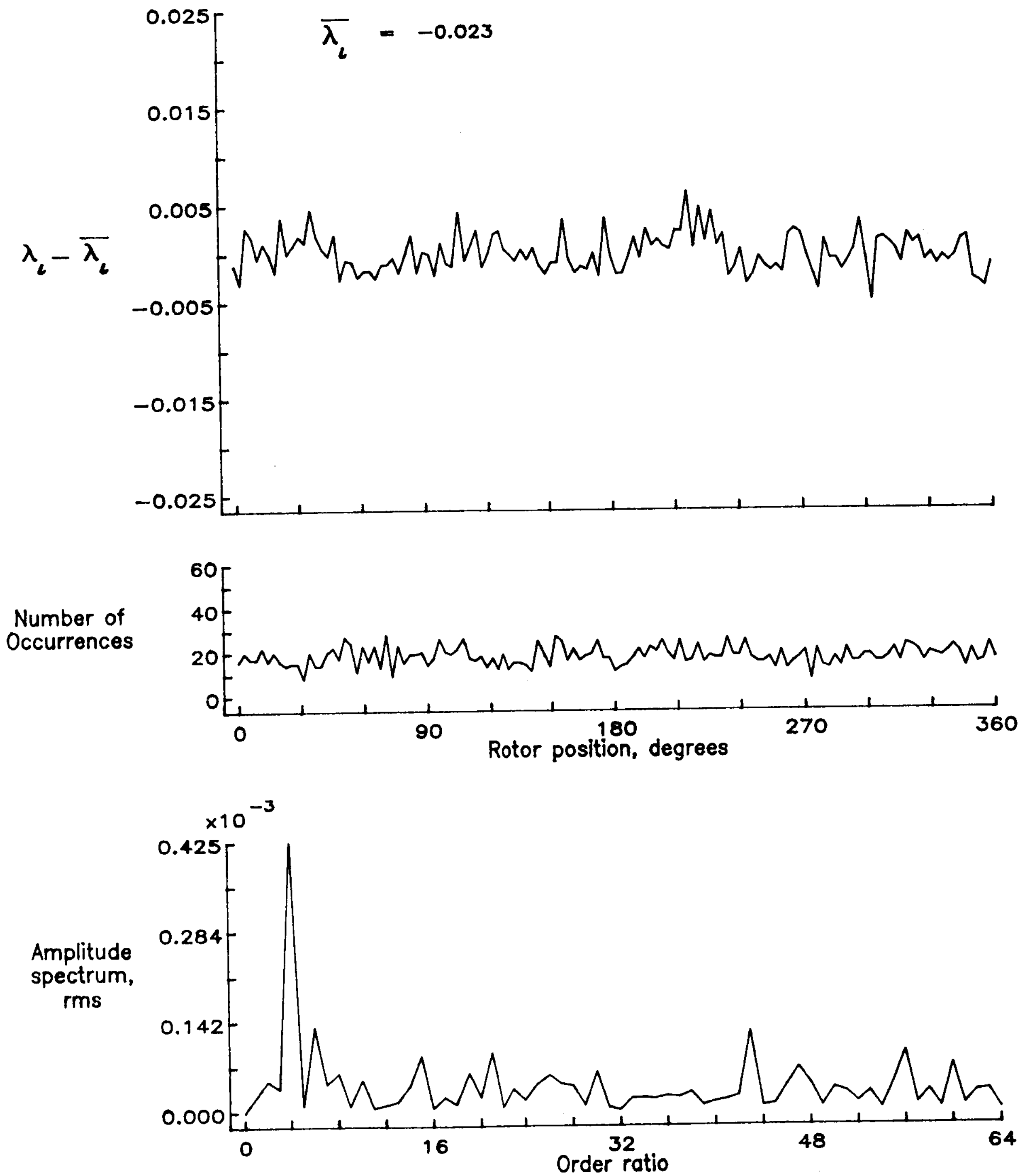


Figure 41.– Induced inflow velocity measured at 30 degrees and r/R of 1.04.



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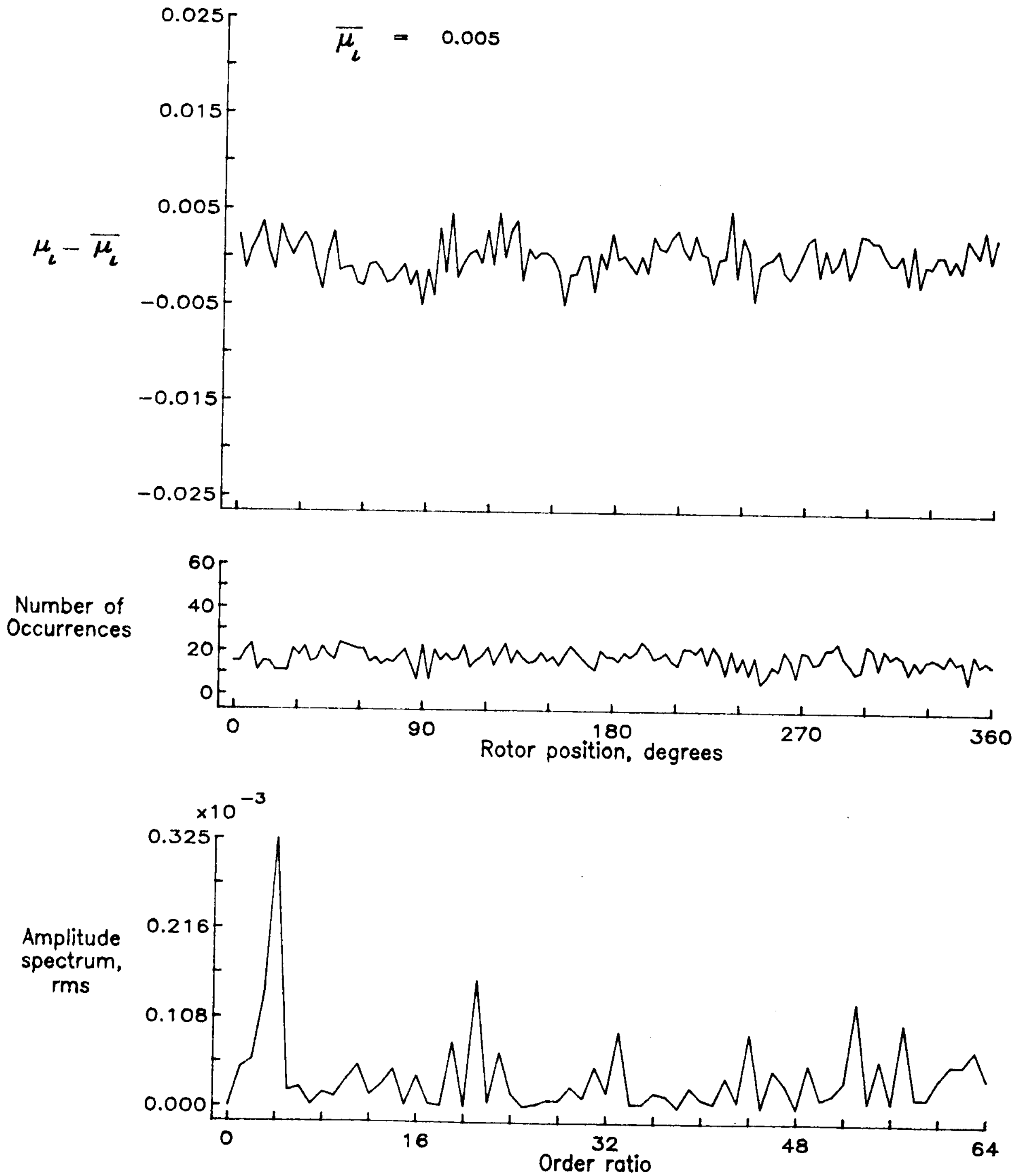
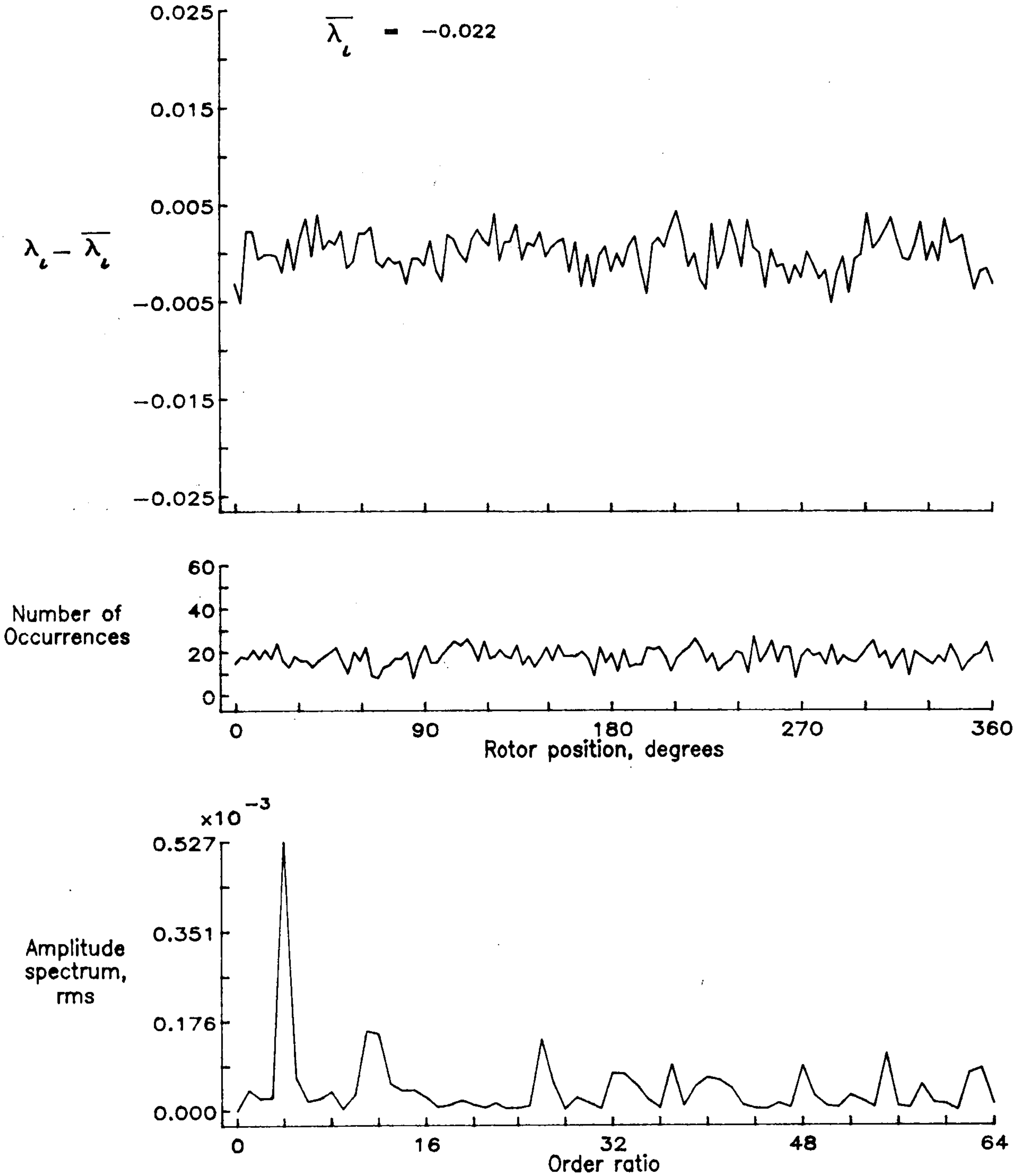


Figure 42.– Induced inflow velocity measured at 30 degrees and r/R of 1.10.



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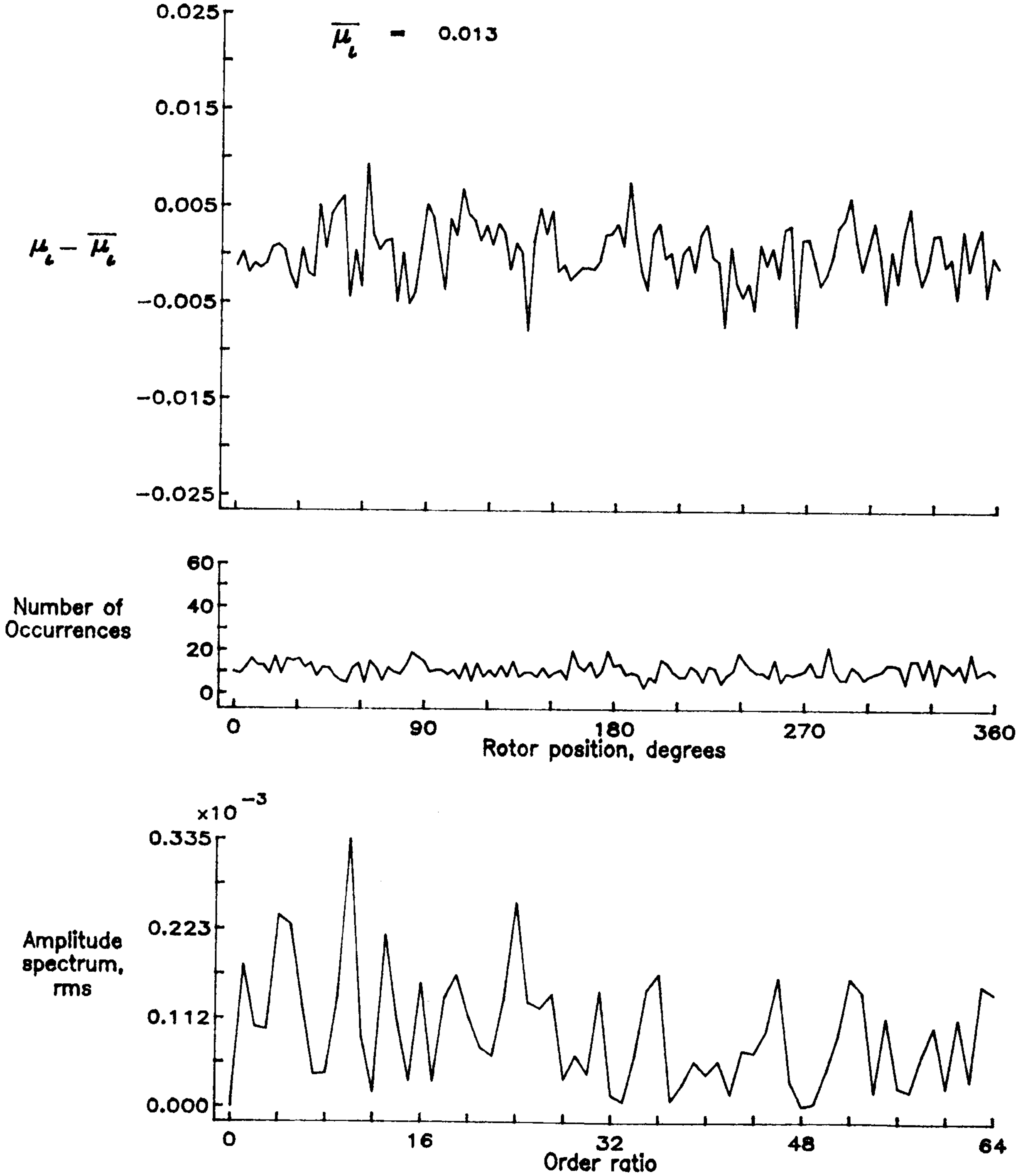
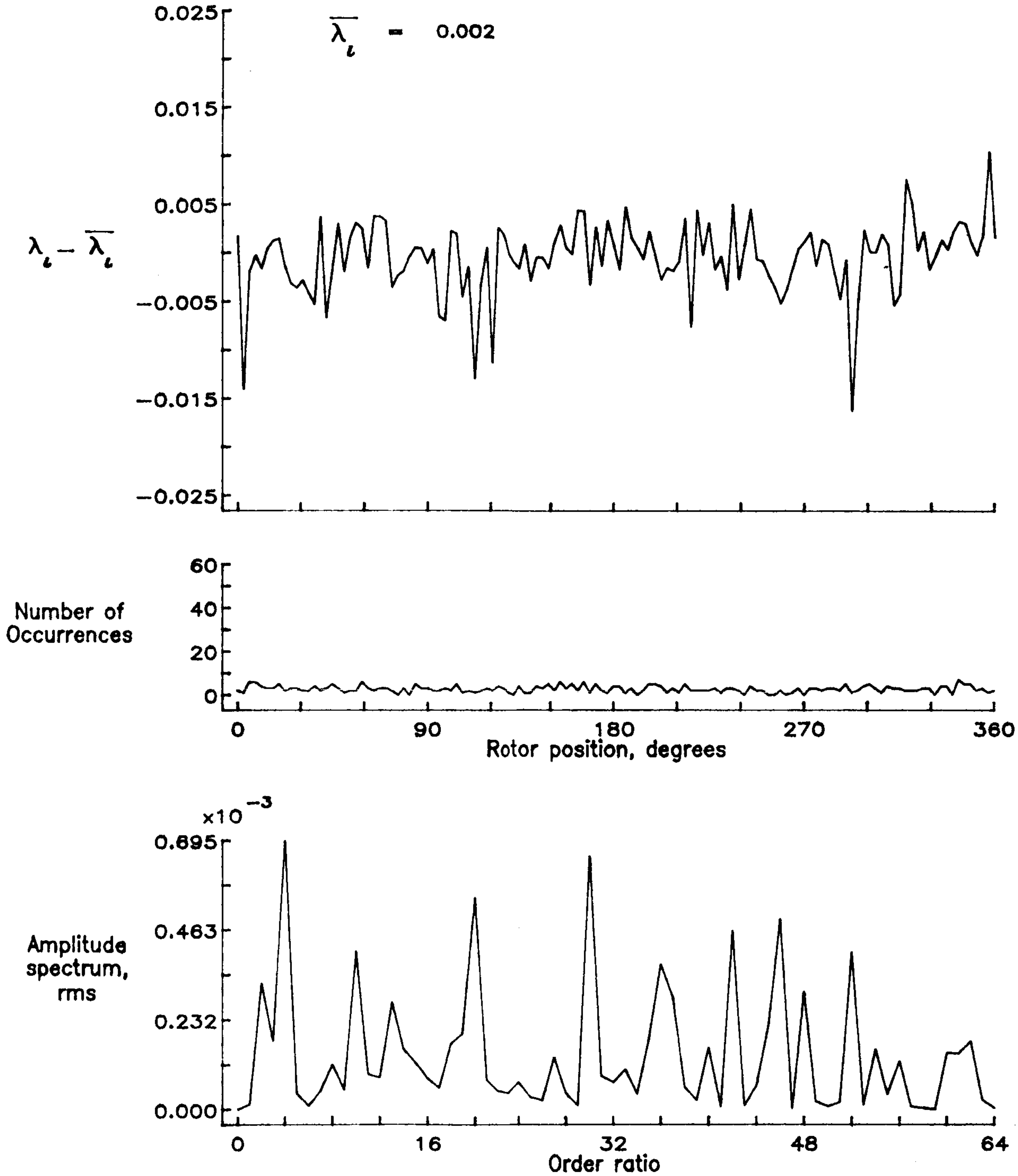


Figure 43.– Induced inflow velocity measured at 60 degrees and r/R of 0.20.



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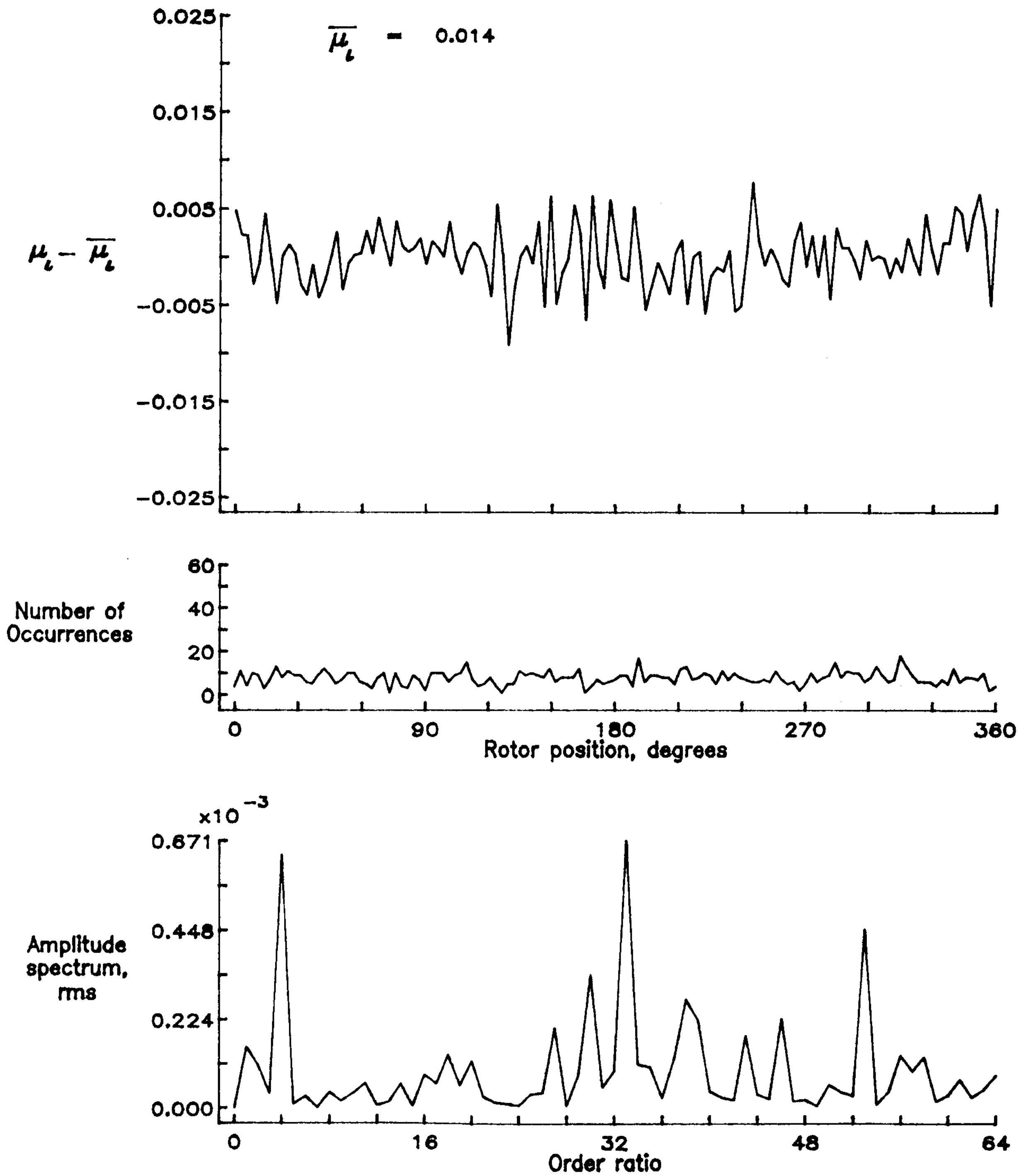
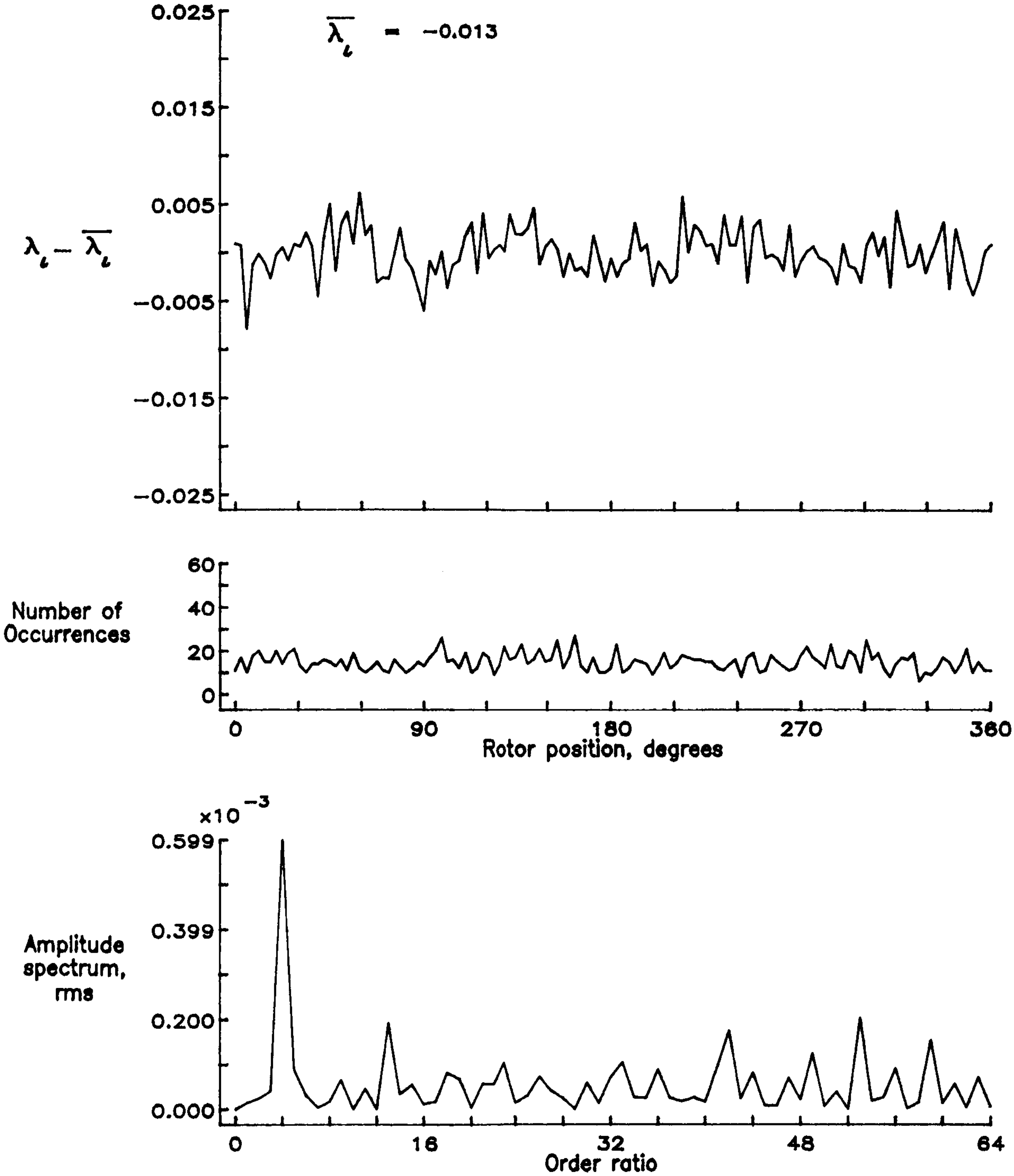


Figure 44.– Induced inflow velocity measured at 60 degrees and r/R of 0.40.



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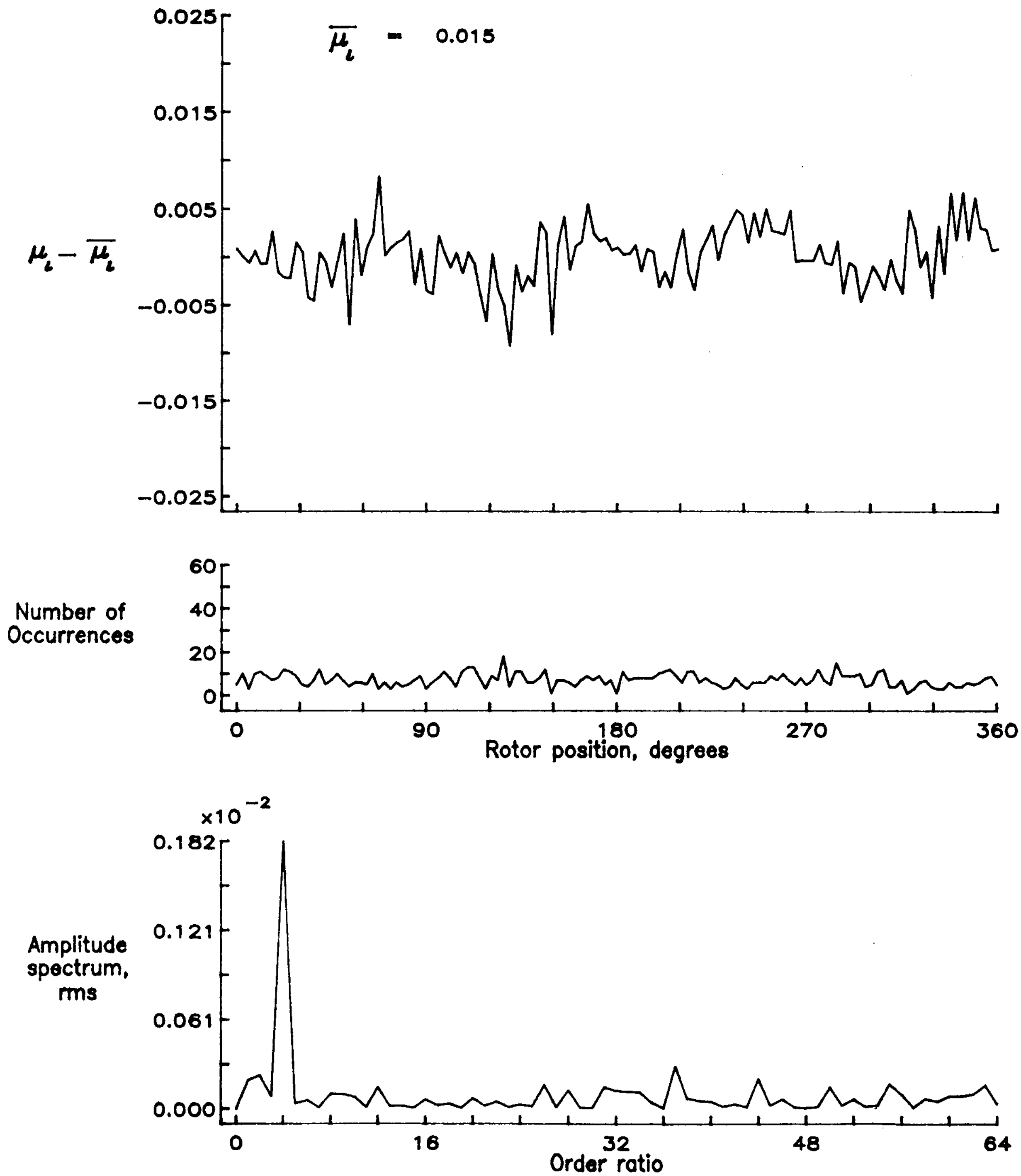
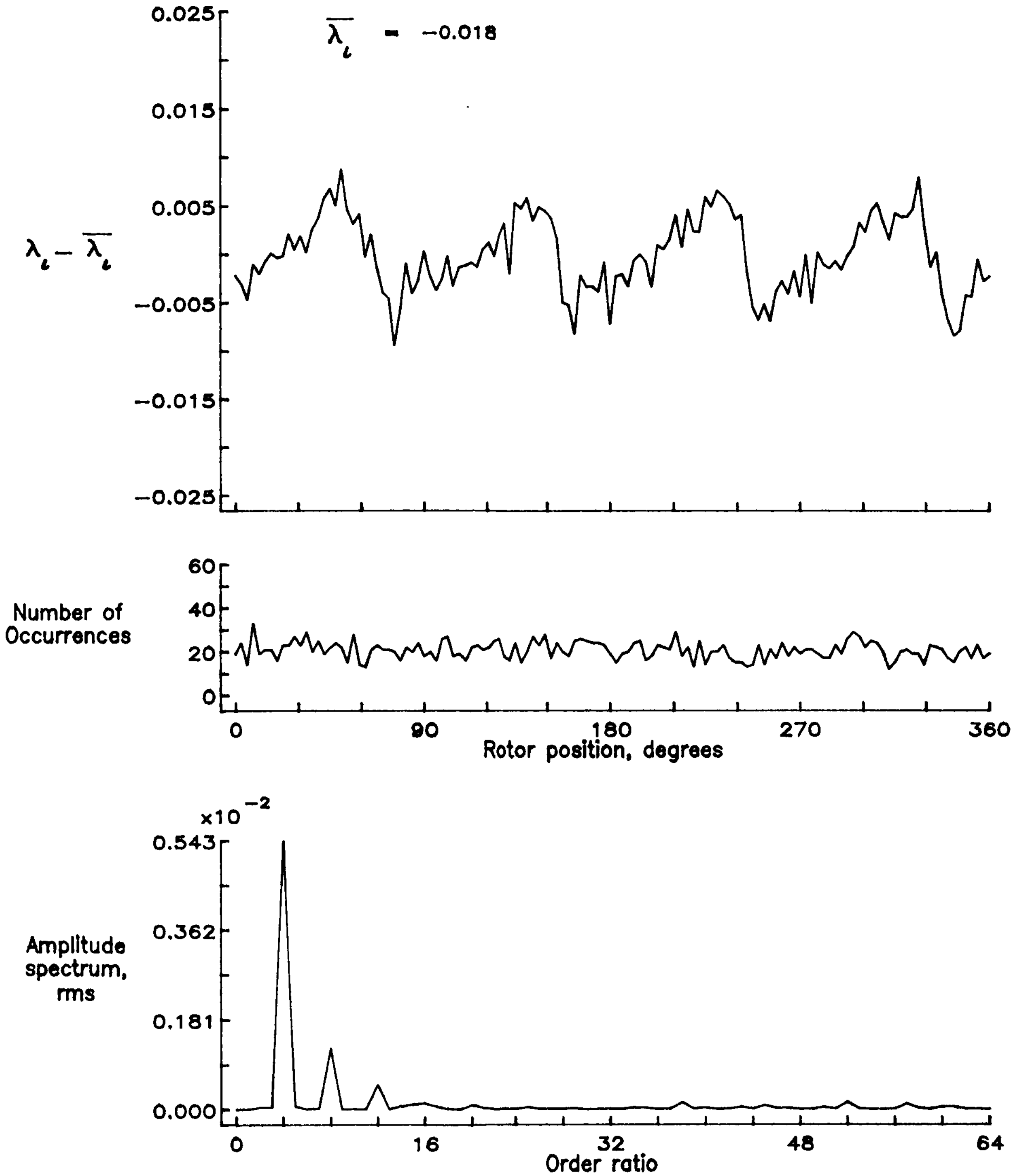


Figure 45.– Induced inflow velocity measured at 60 degrees and r/R of 0.50.



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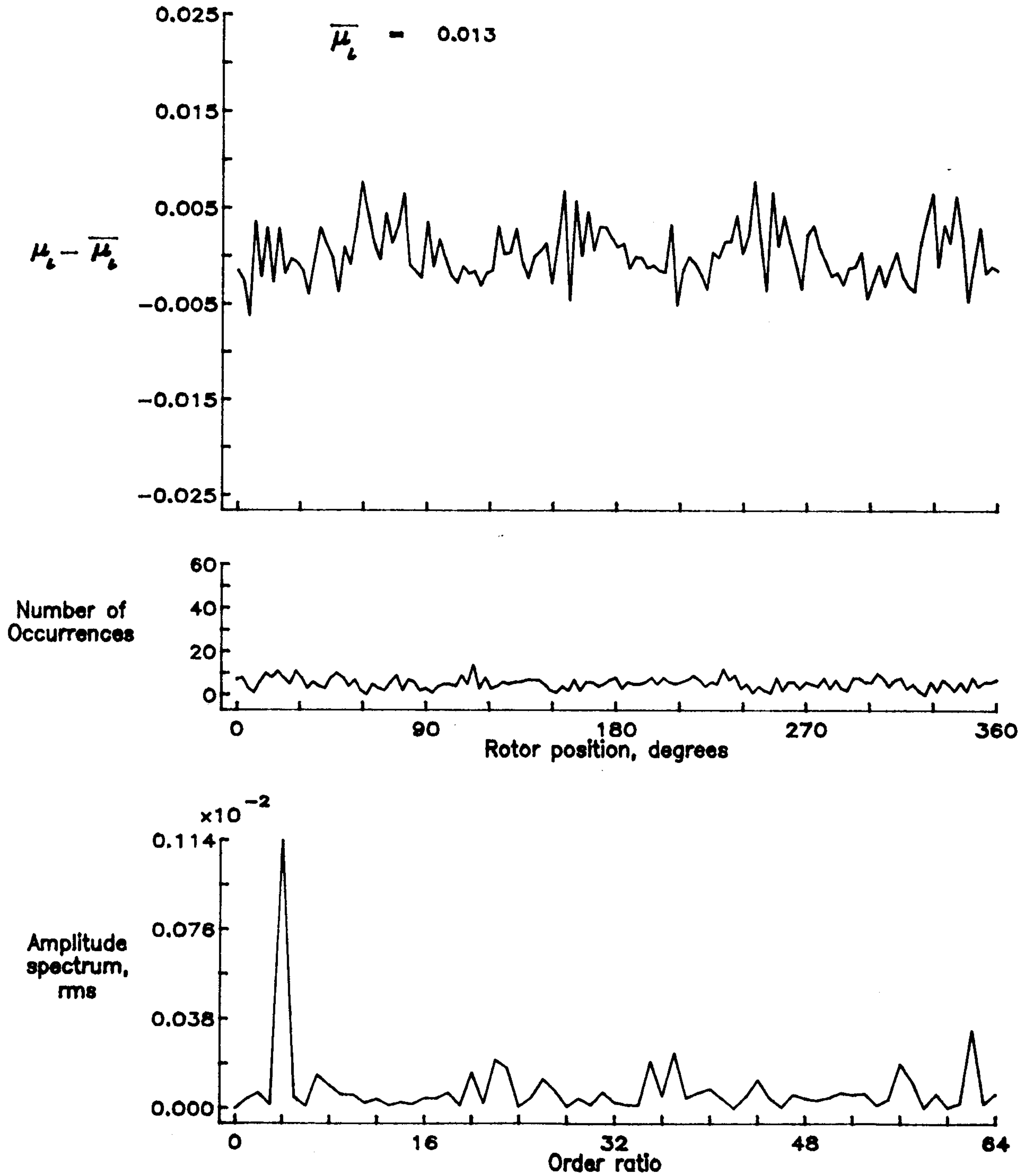
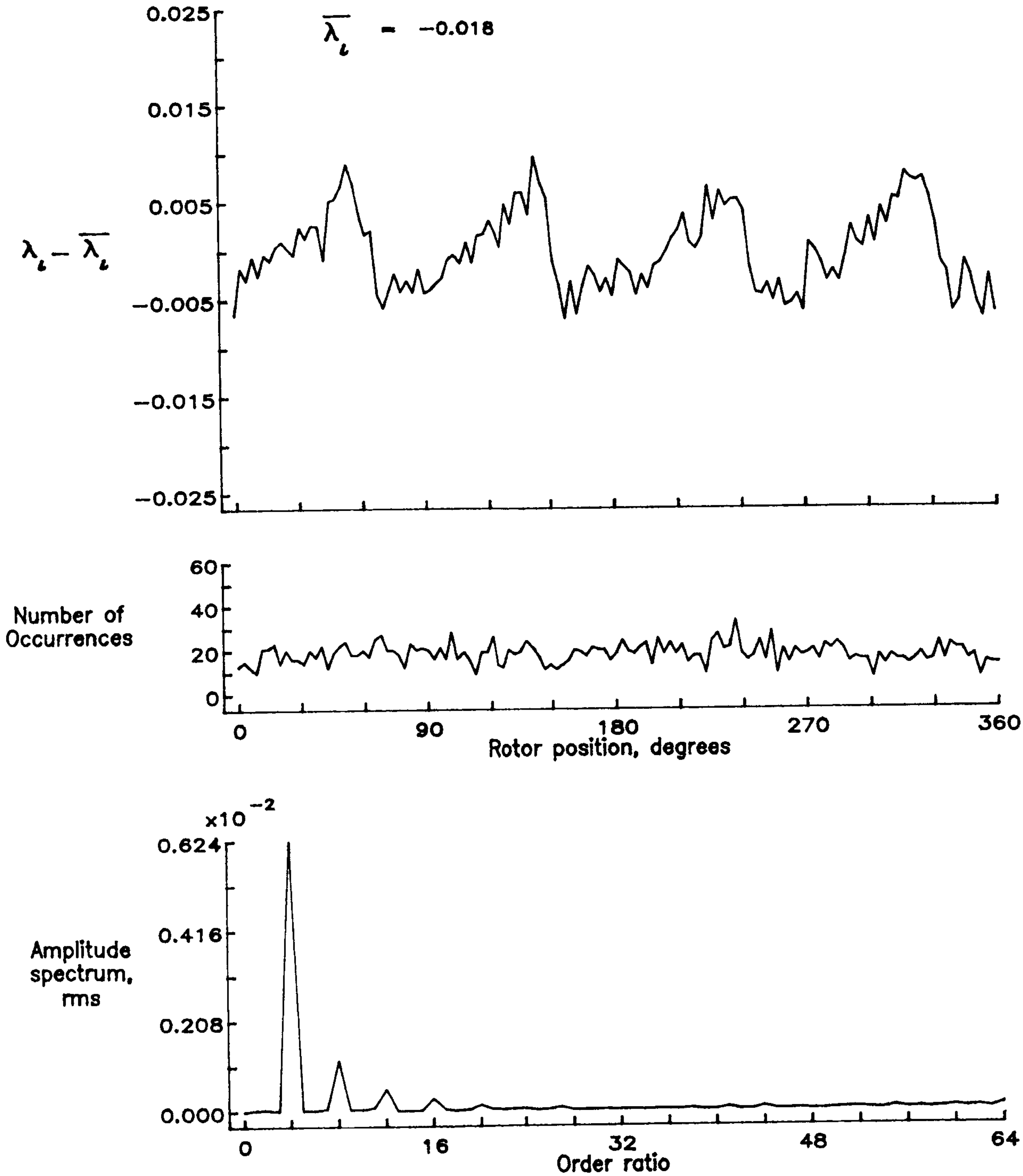


Figure 46.– Induced inflow velocity measured at 60 degrees and r/R of 0.60.



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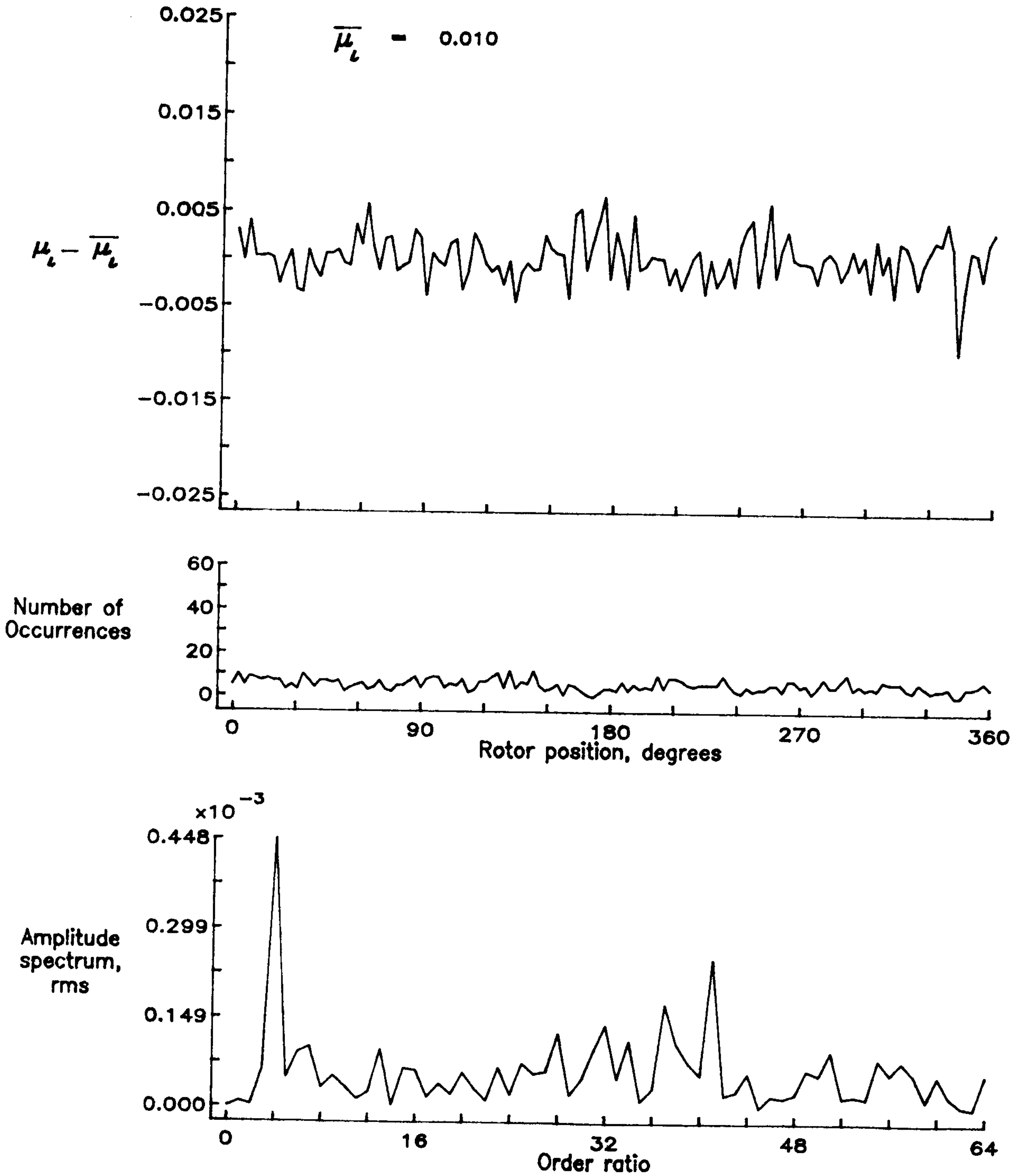

Figure 47.– Induced inflow velocity measured at 60 degrees and r/R of 0.70.

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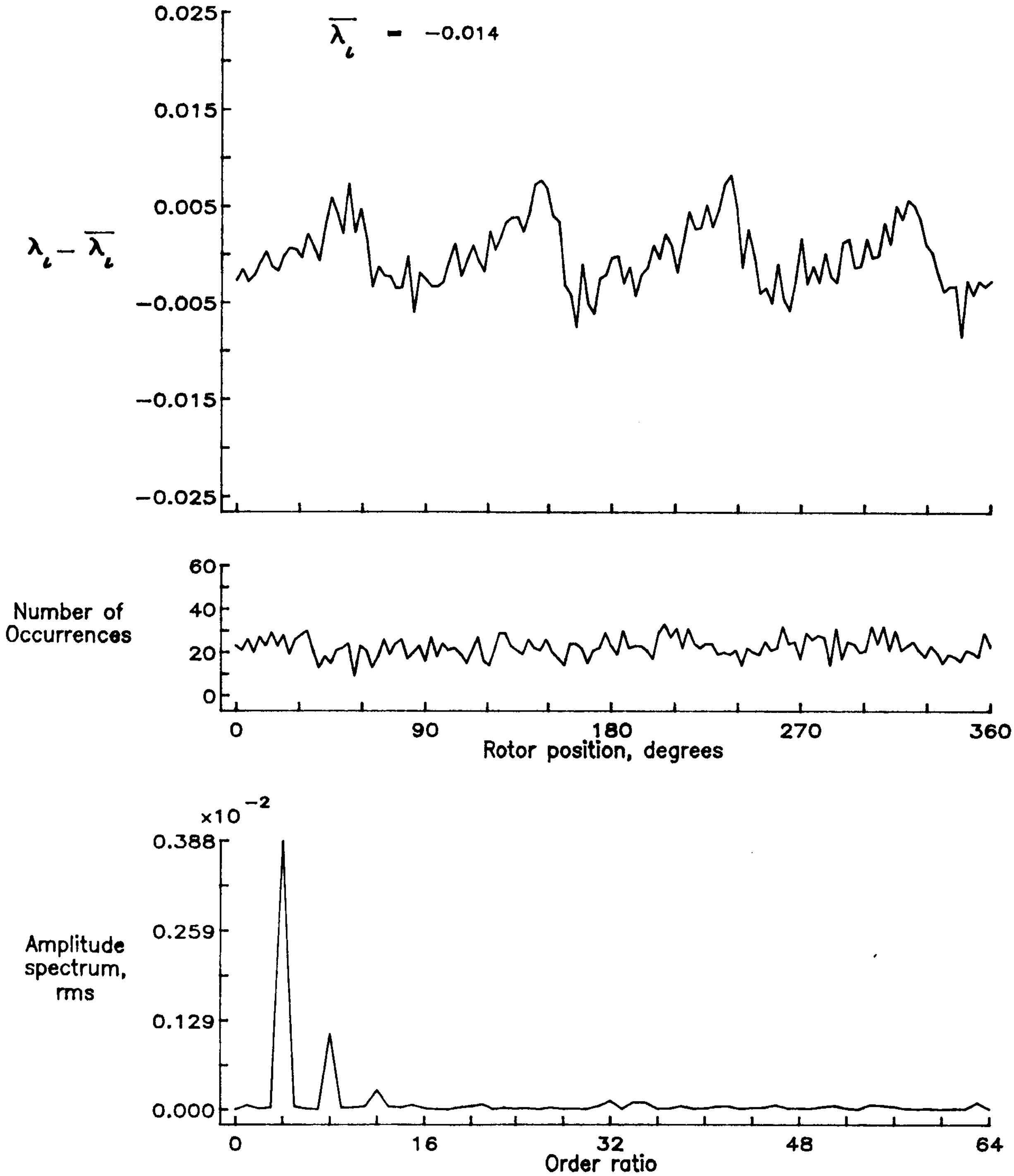


Figure 47.– Concluded.

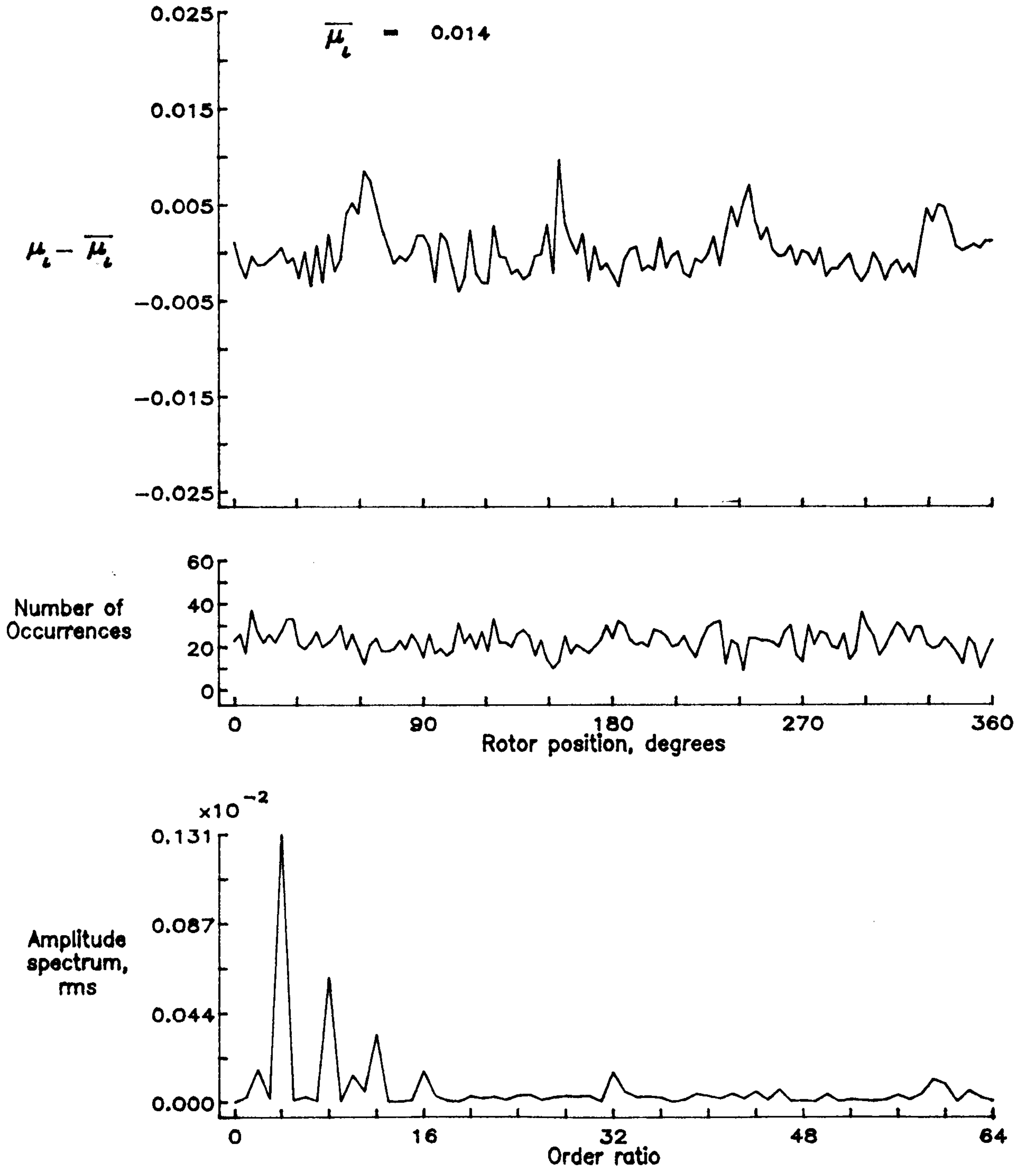
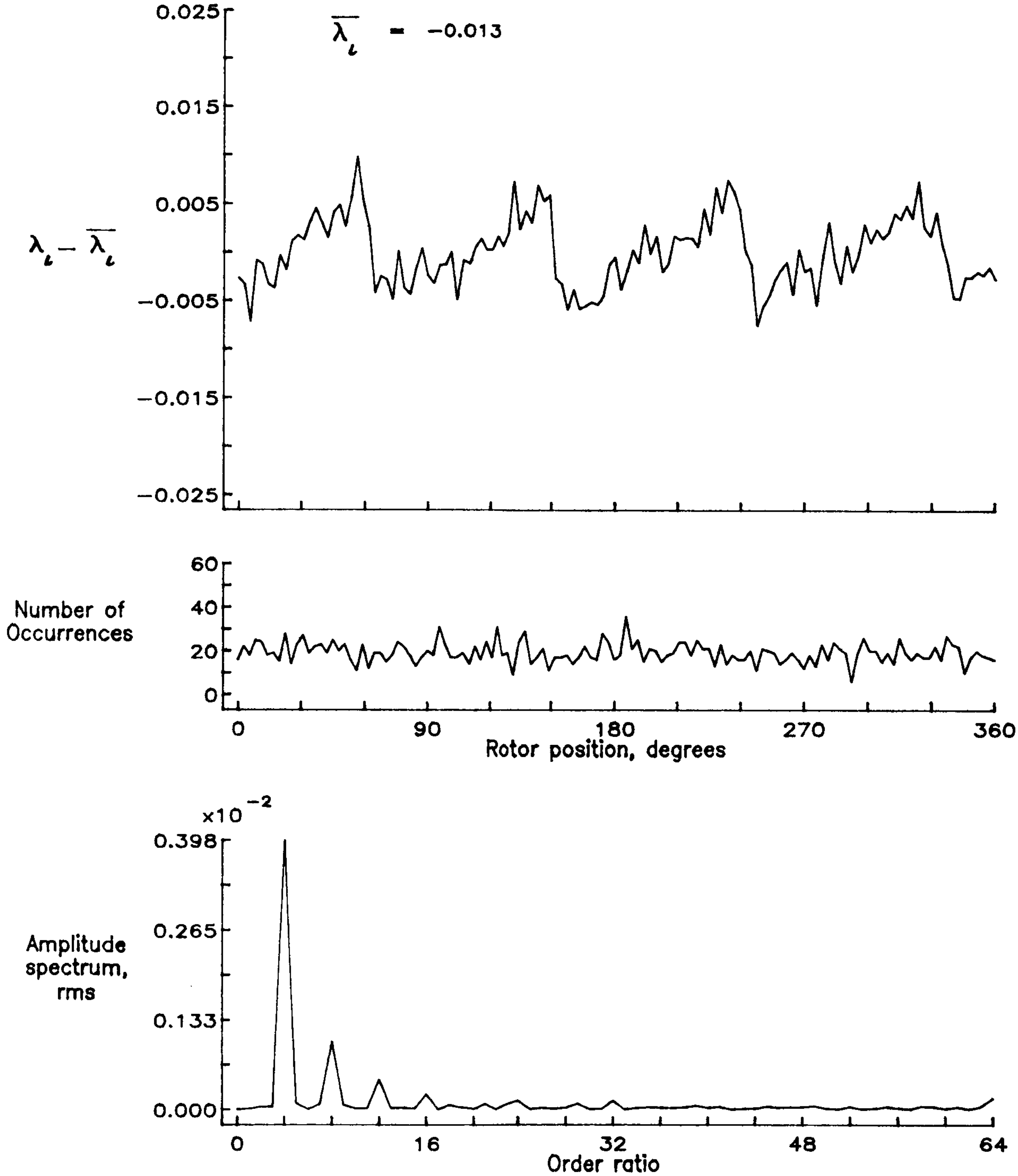


Figure 48.– Induced inflow velocity measured at 60 degrees and r/R of 0.74.



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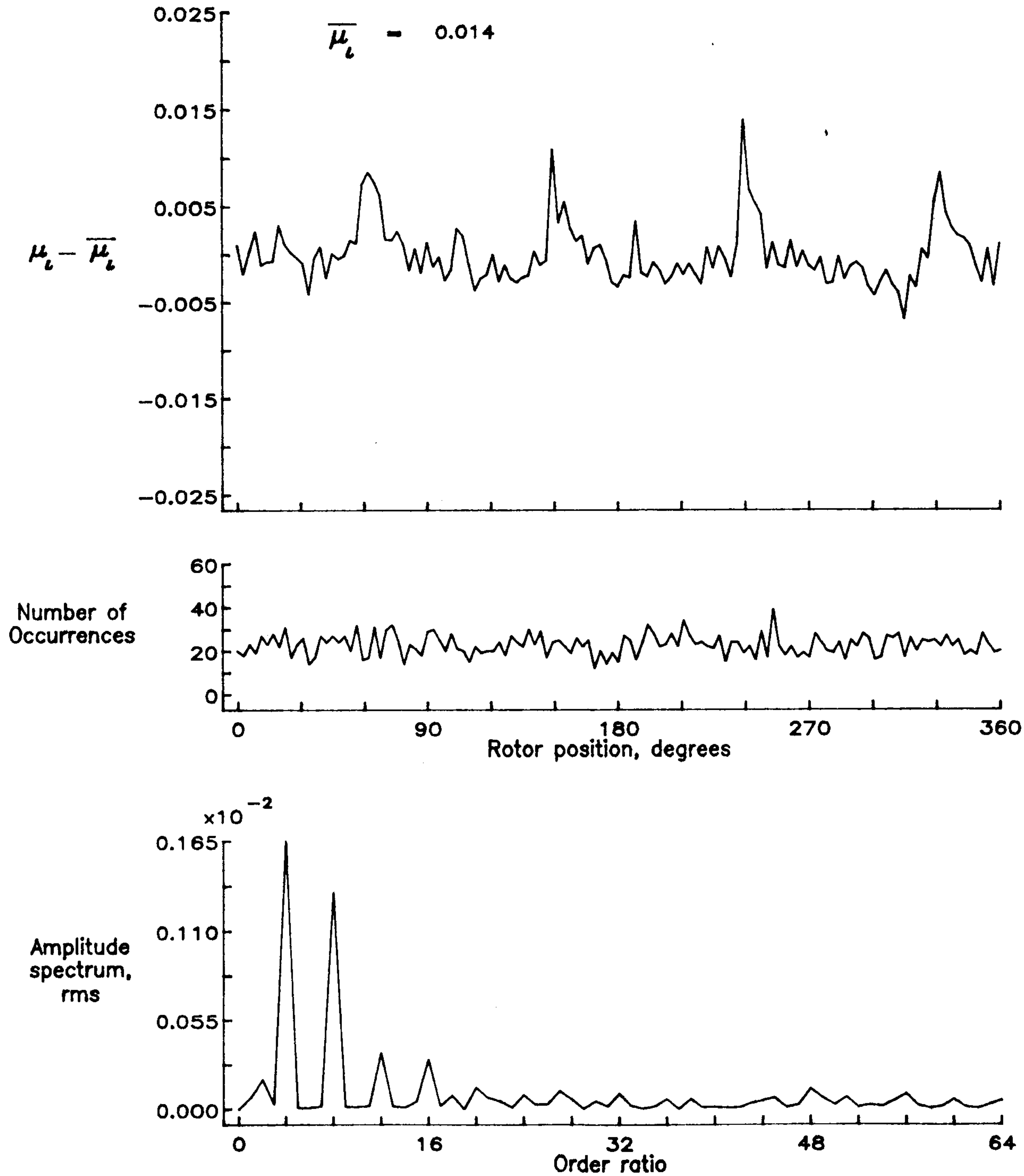


Figure 49.– Induced inflow velocity measured at 60 degrees and r/R of 0.78.

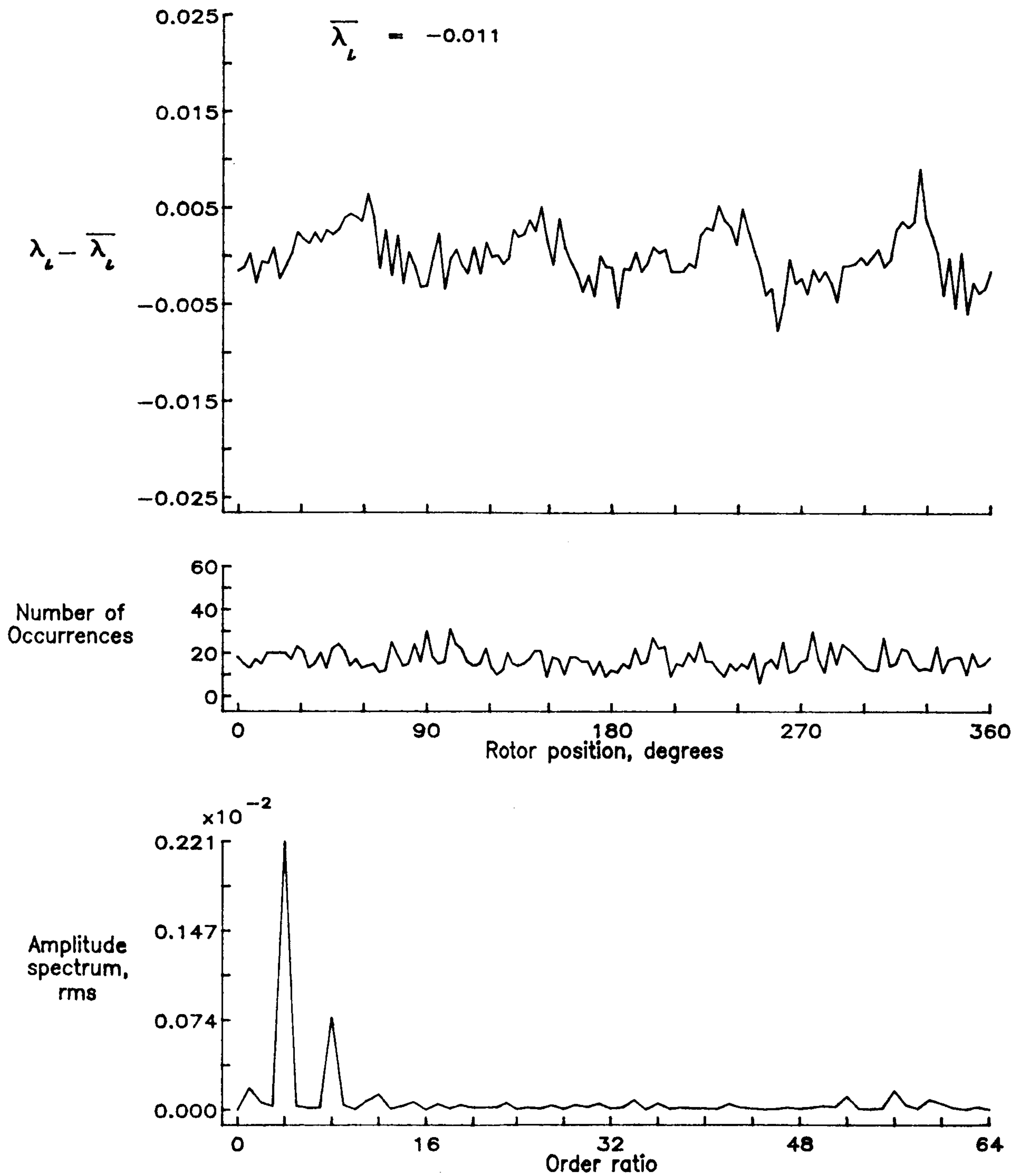


Figure 49.– Concluded.

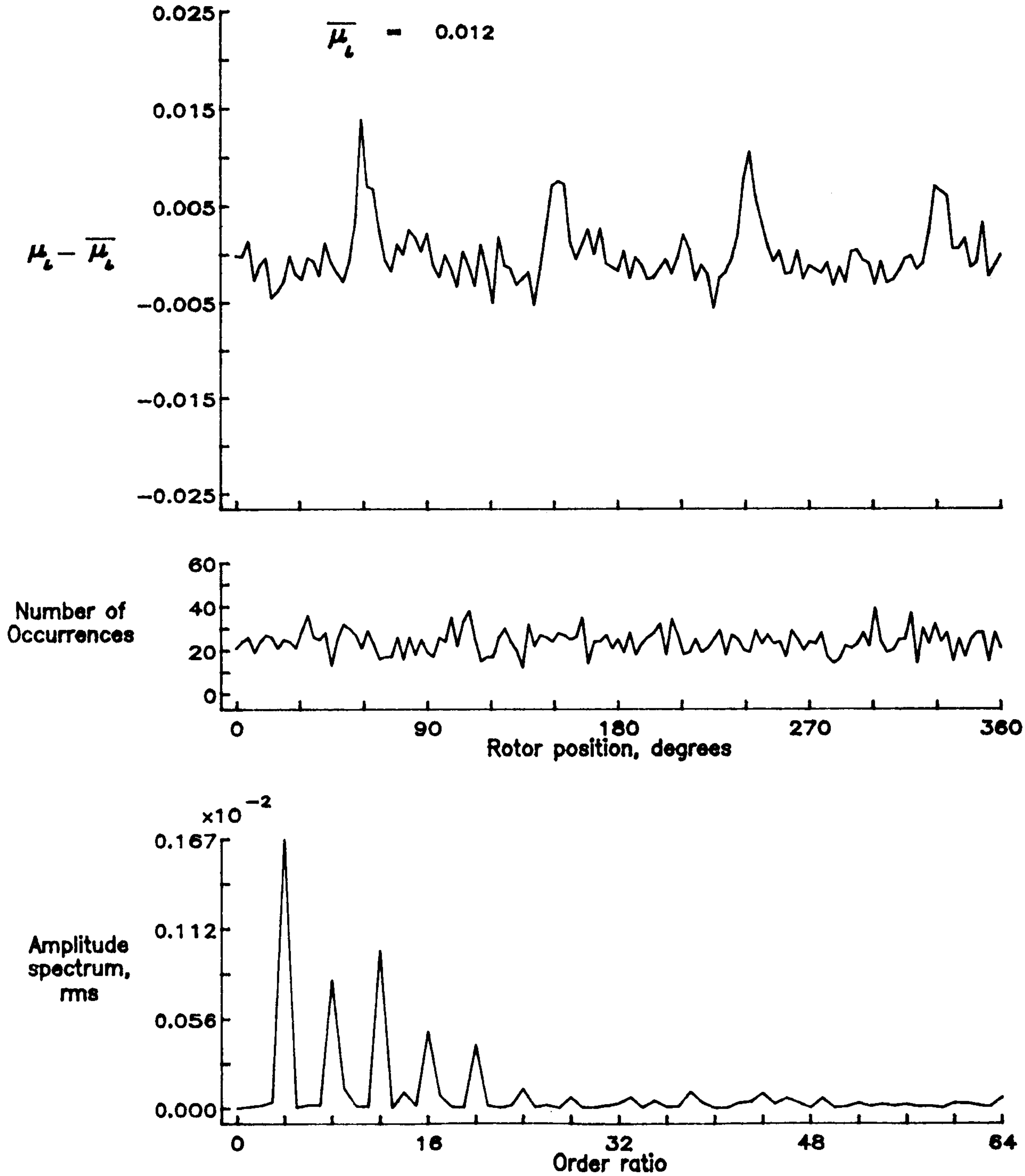


Figure 50.– Induced inflow velocity measured at 60 degrees and r/R of 0.82.

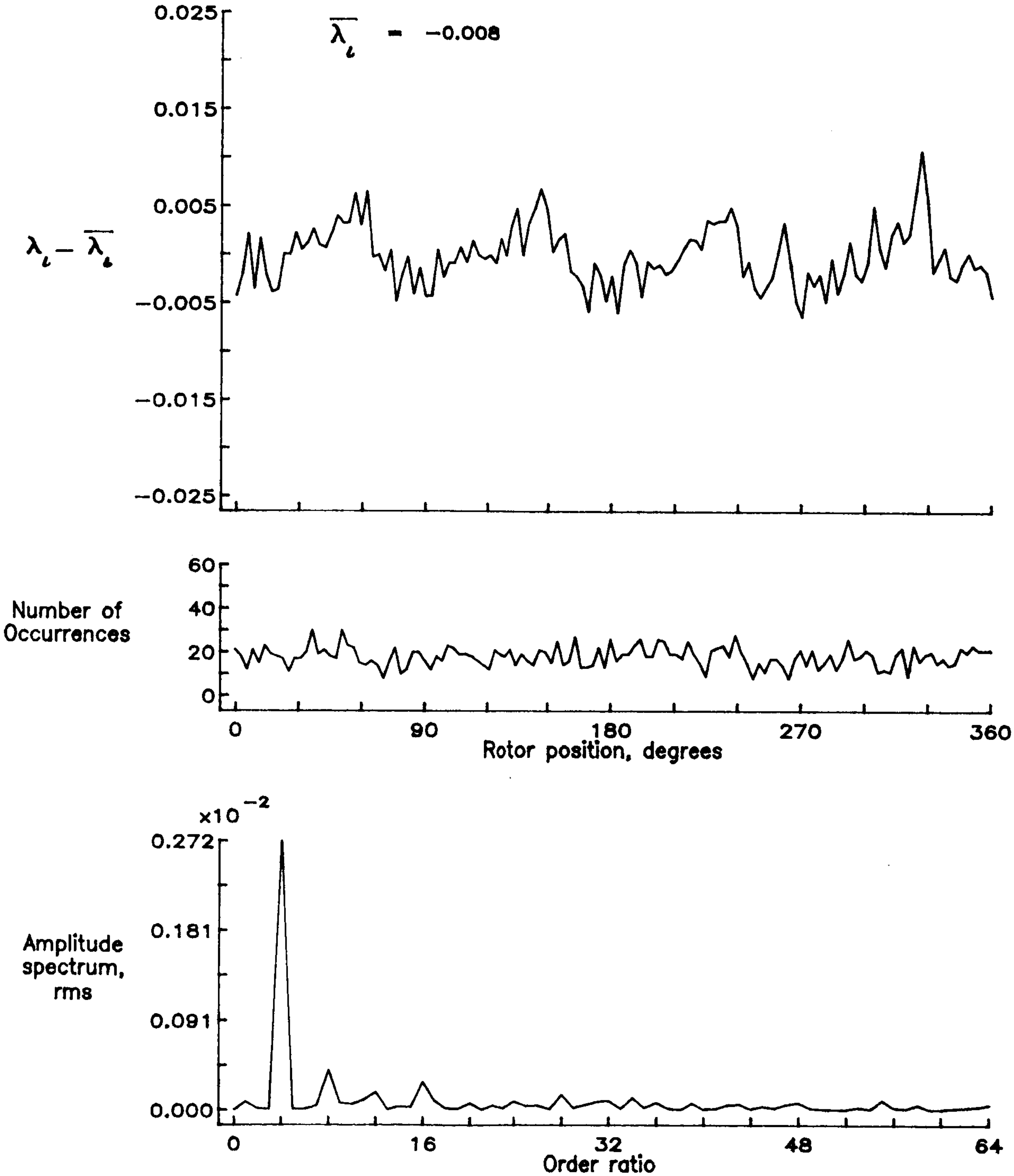


Figure 50.– Concluded.

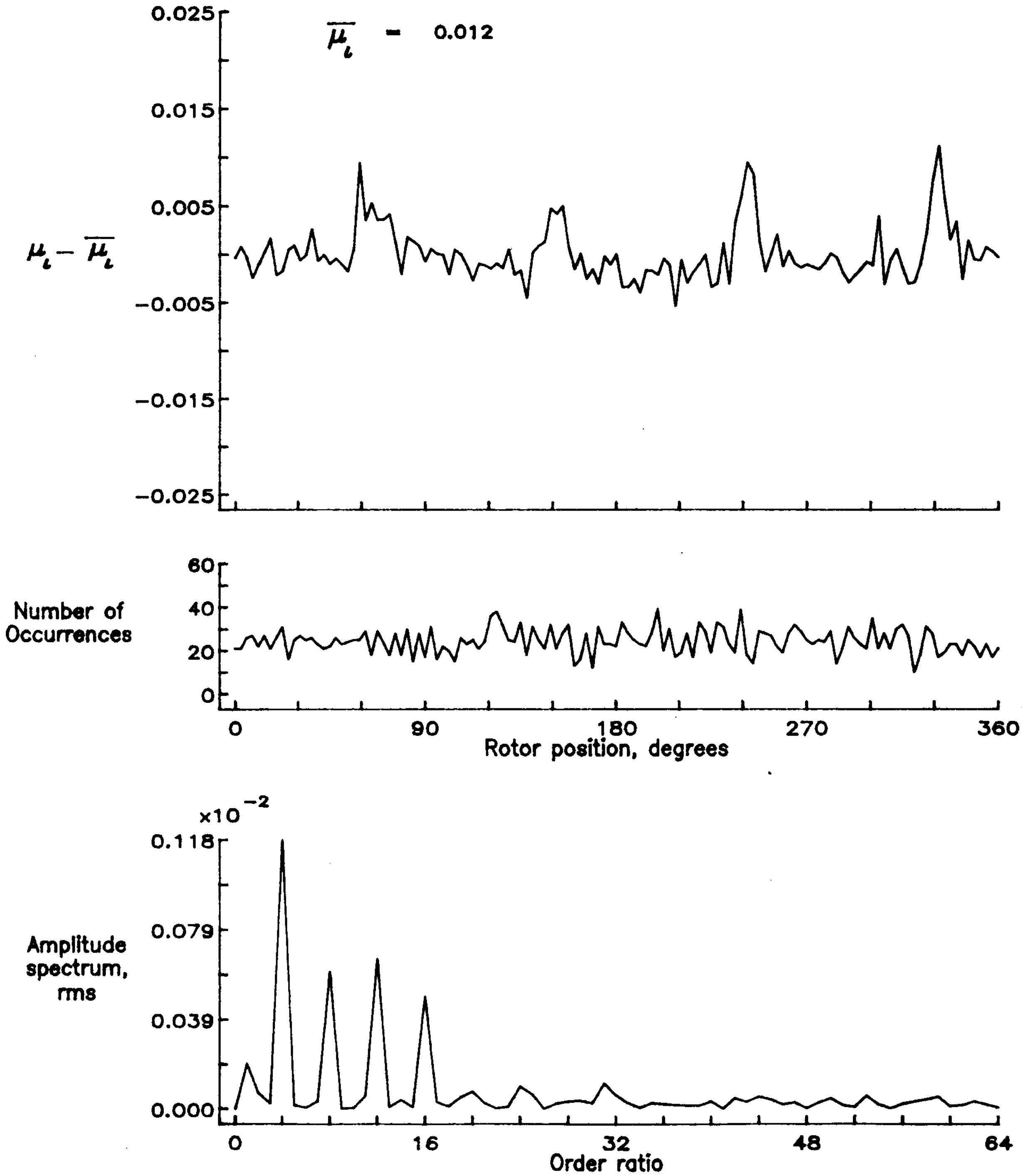


Figure 51.– Induced inflow velocity measured at 60 degrees and r/R of 0.86.

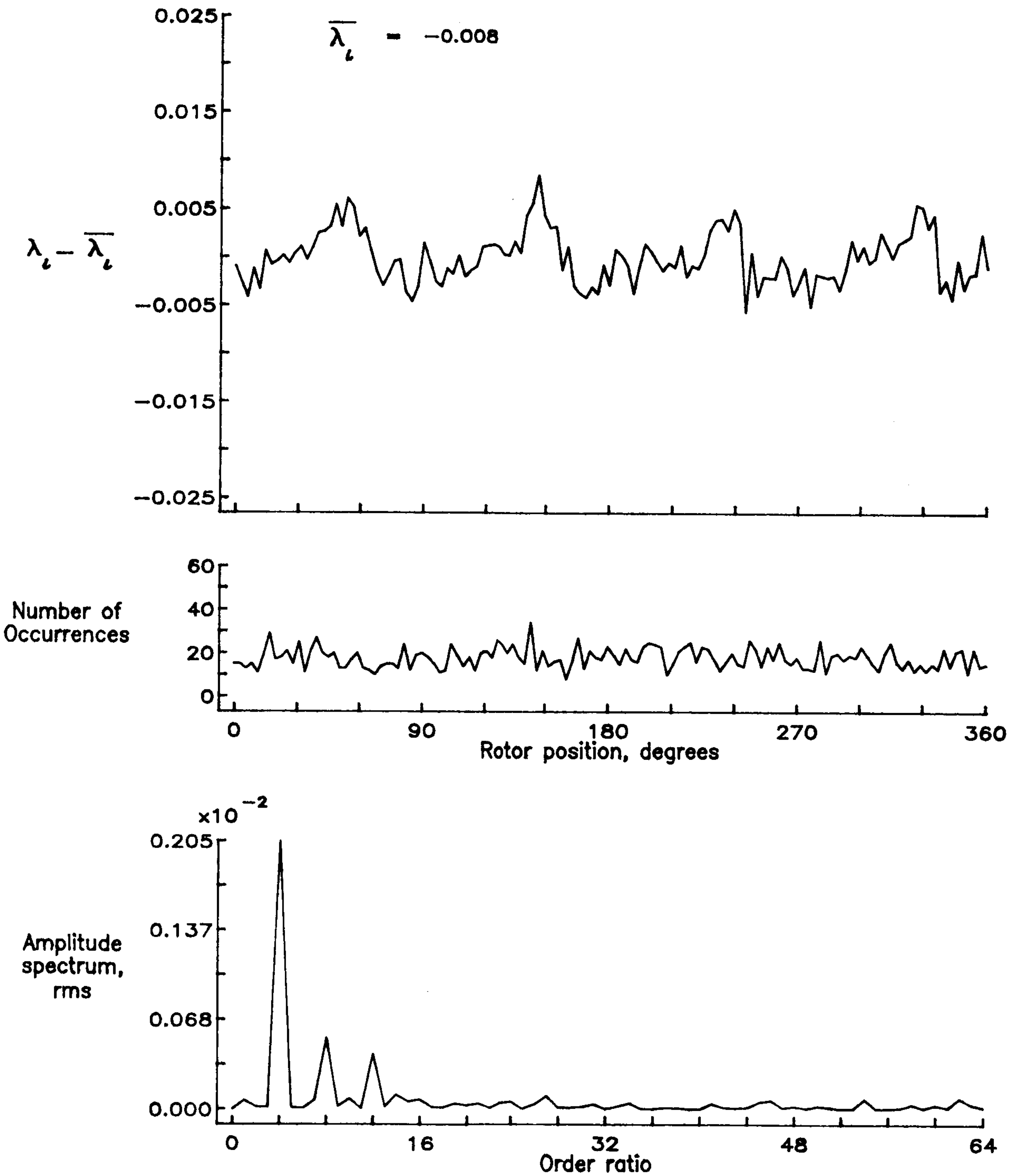


Figure 51.– Concluded.

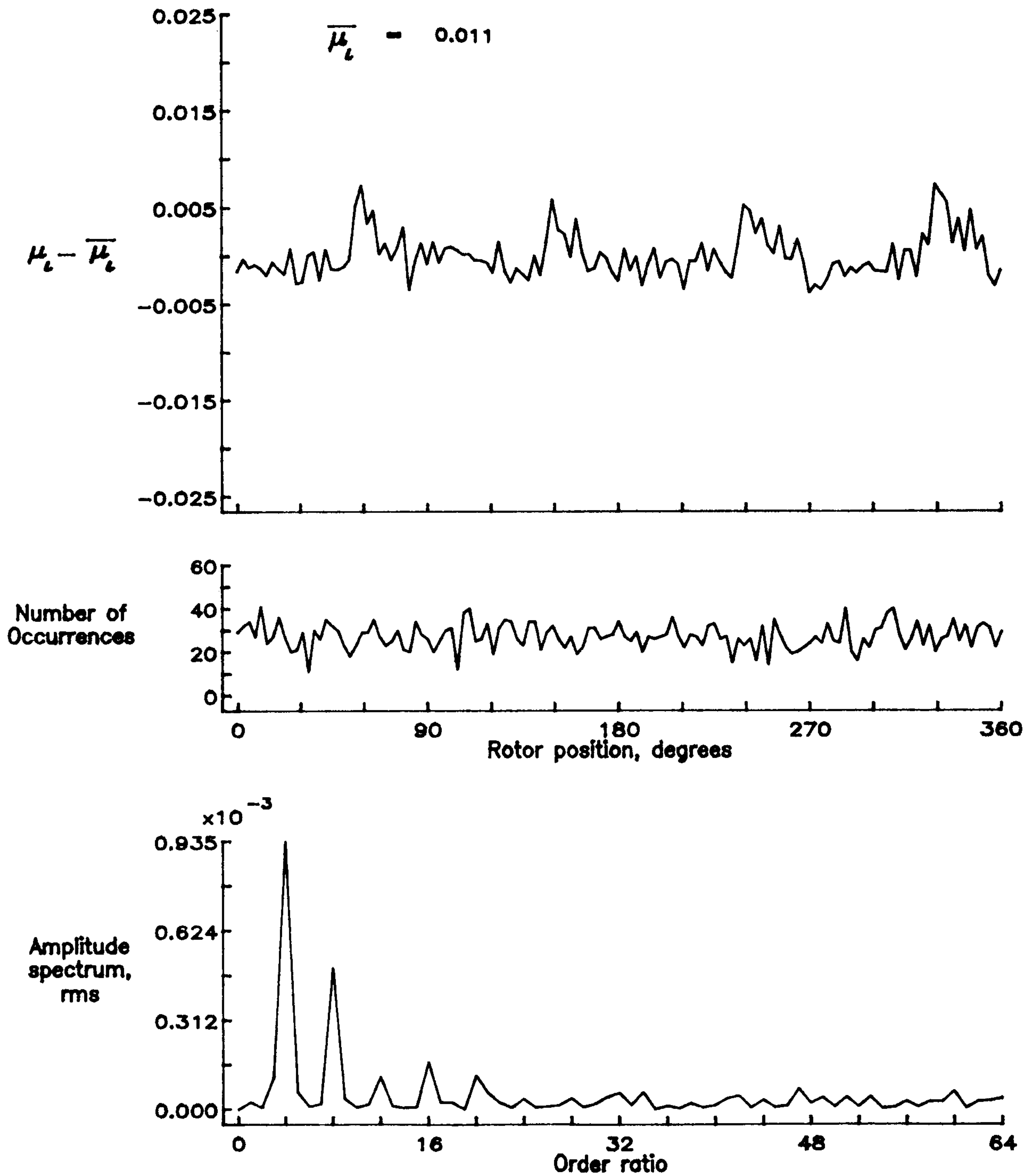
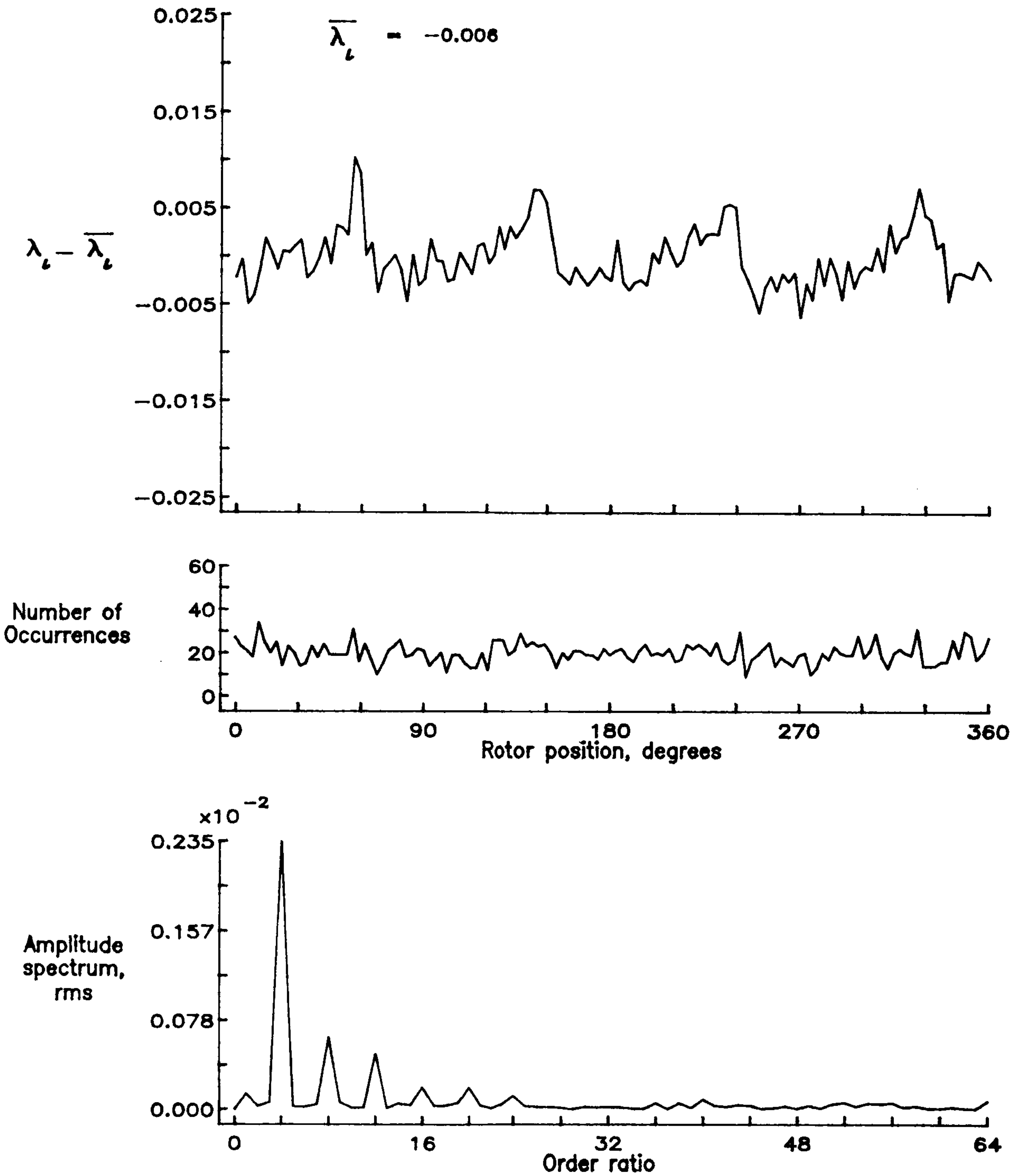


Figure 52.– Induced inflow velocity measured at 60 degrees and r/R of 0.90.



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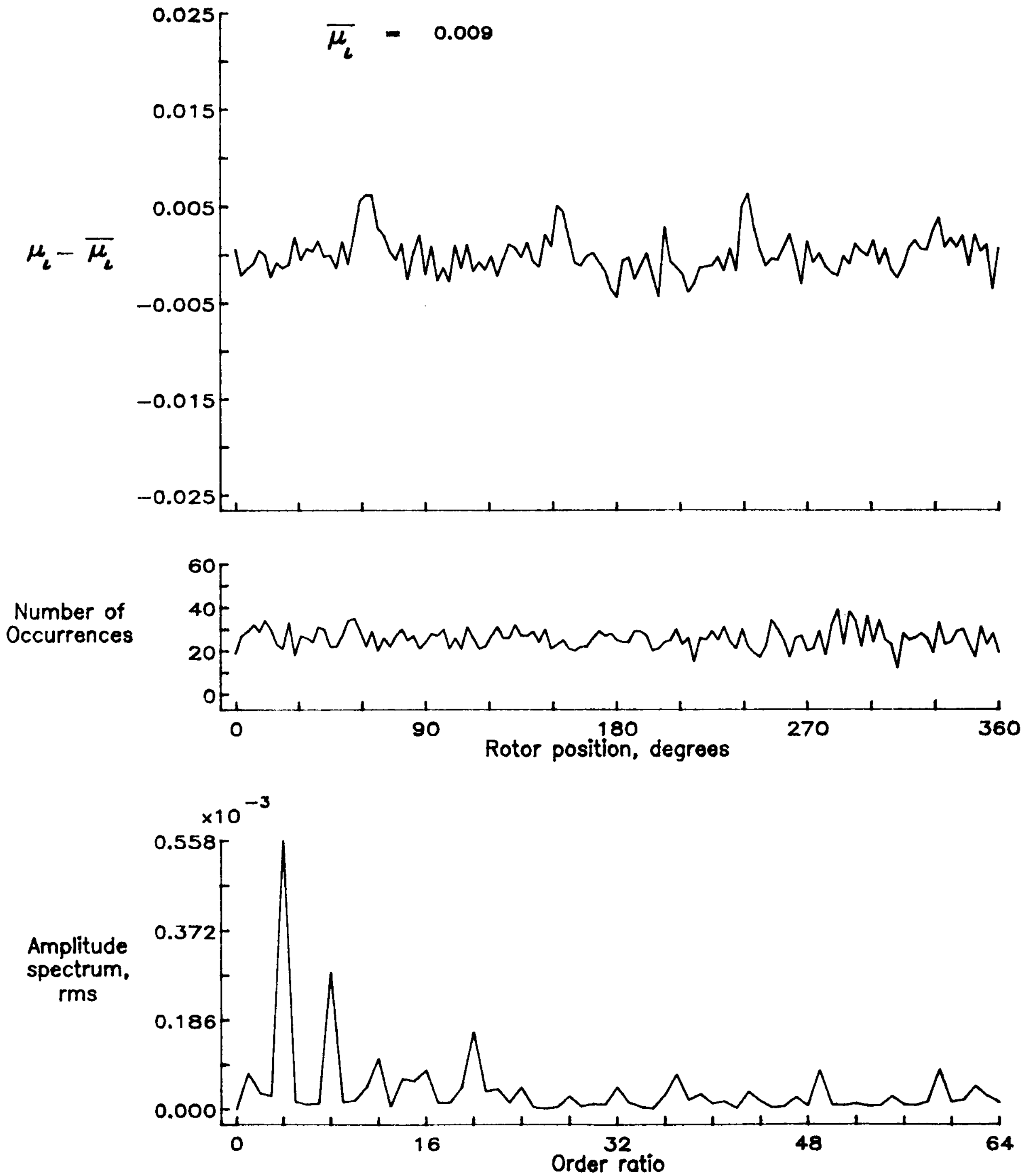


Figure 53.– Induced inflow velocity measured at 60 degrees and r/R of 0.94.

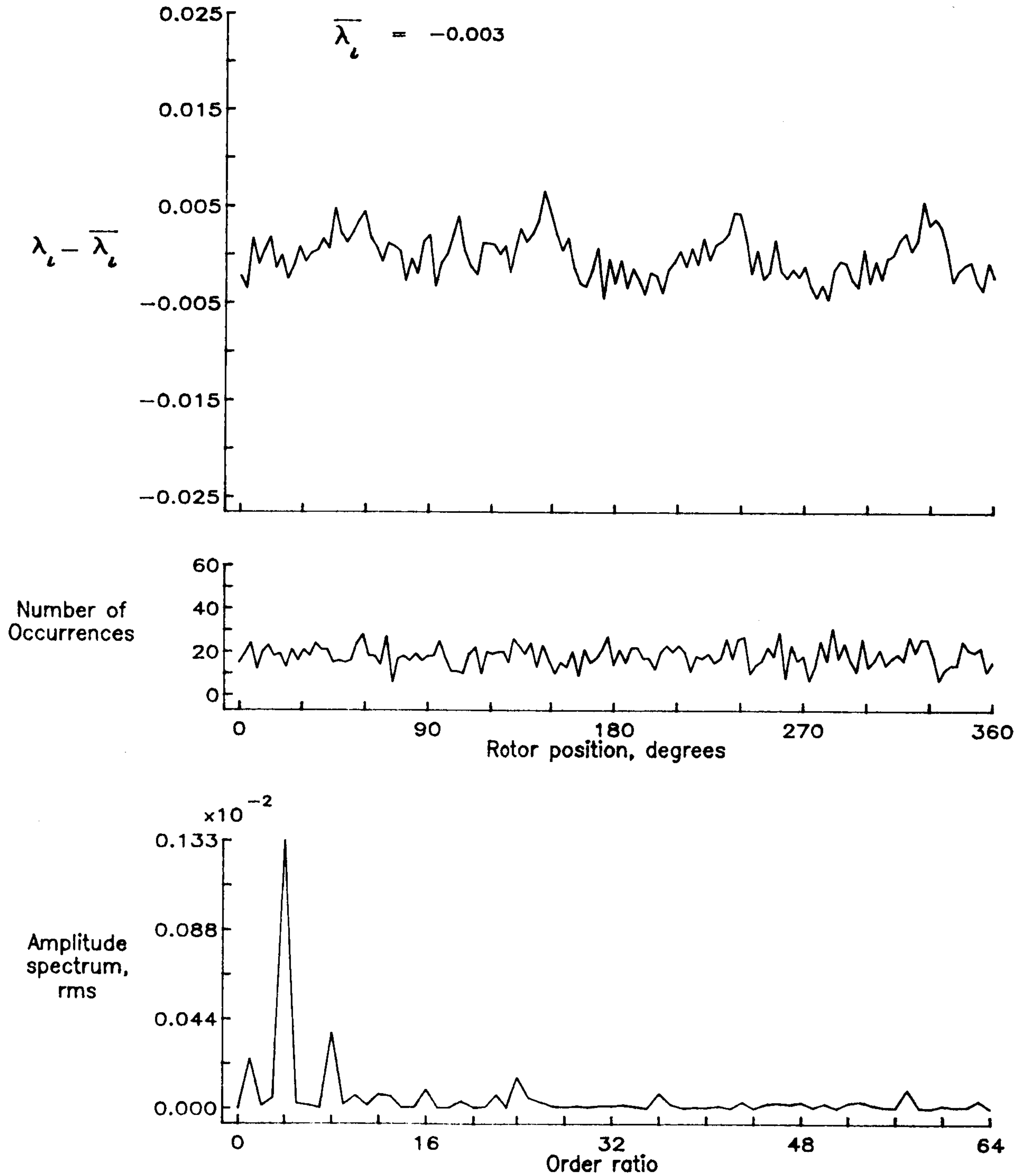


Figure 53.– Concluded.

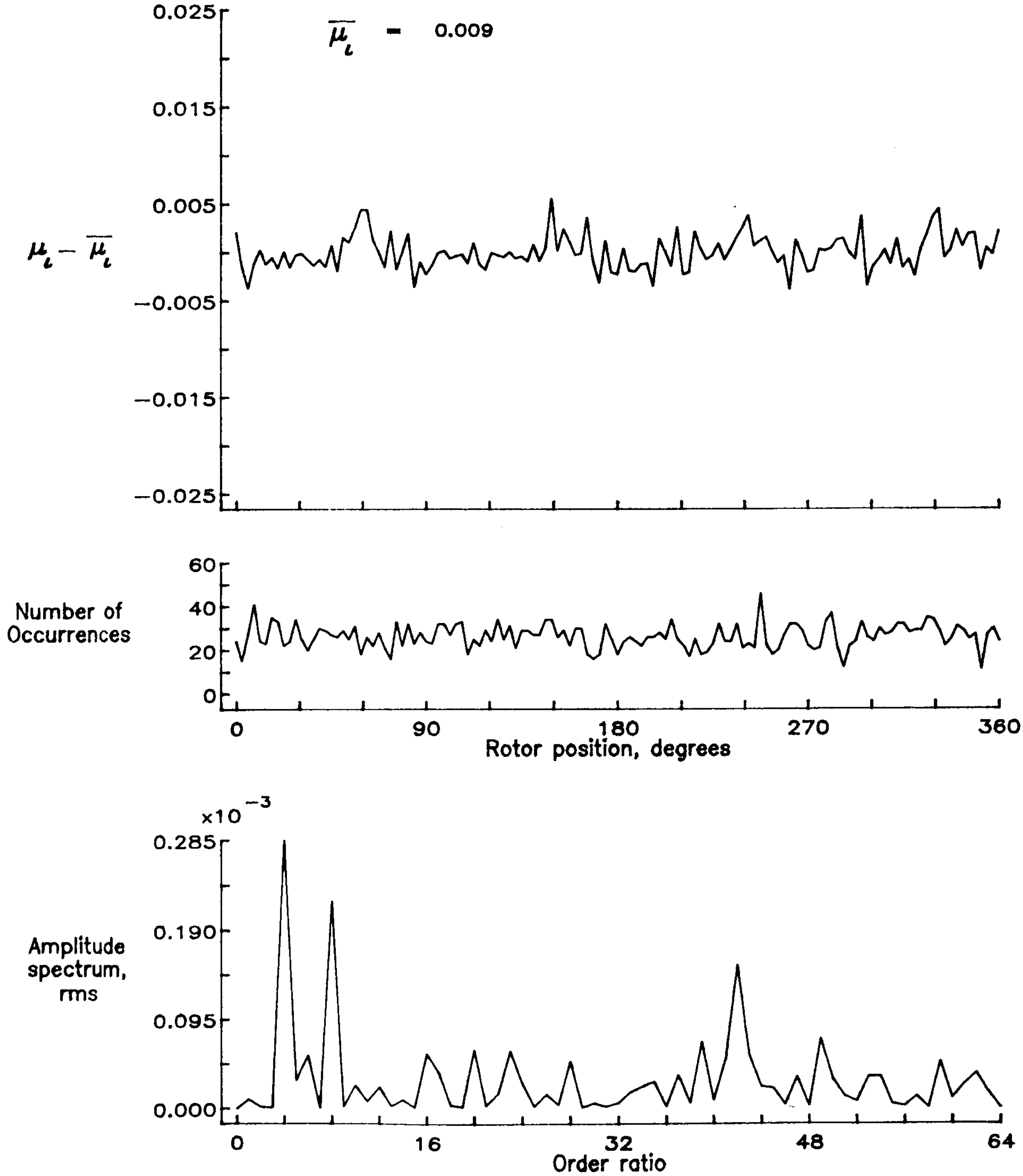


Figure 54.– Induced inflow velocity measured at 60 degrees and r/R of 0.98.

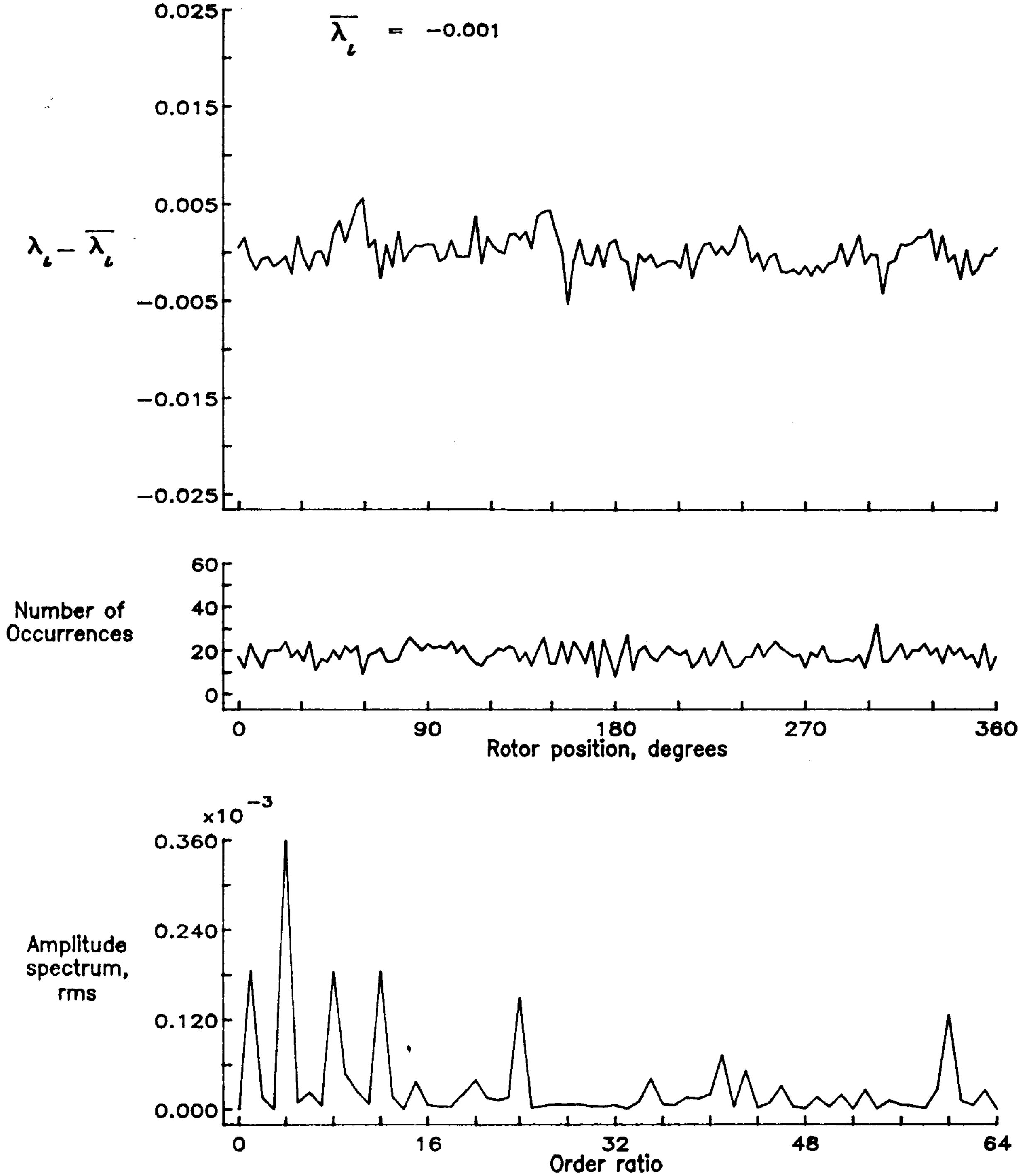


Figure 54.– Concluded.

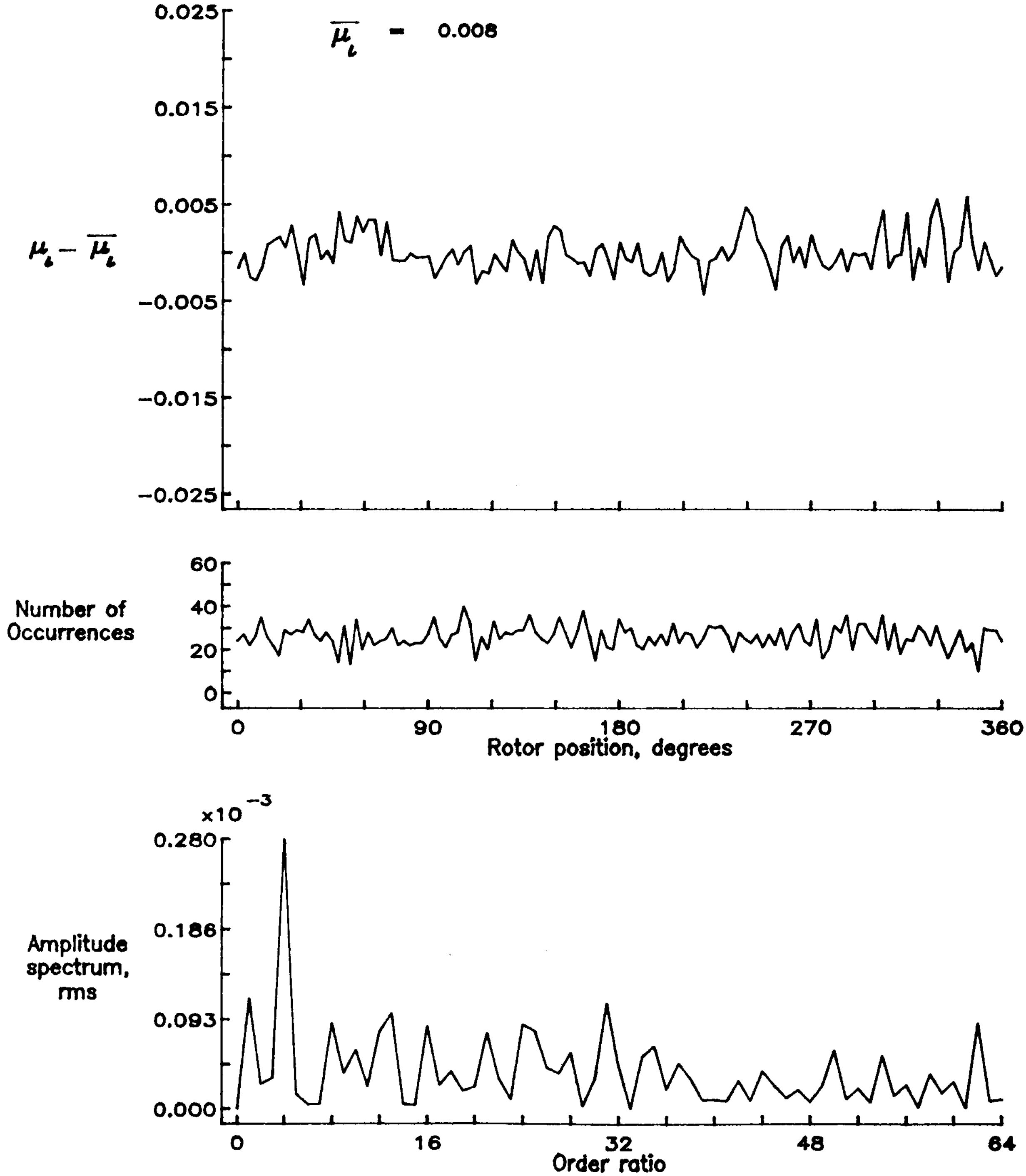


Figure 55.– Induced inflow velocity measured at 60 degrees and r/R of 1.02.

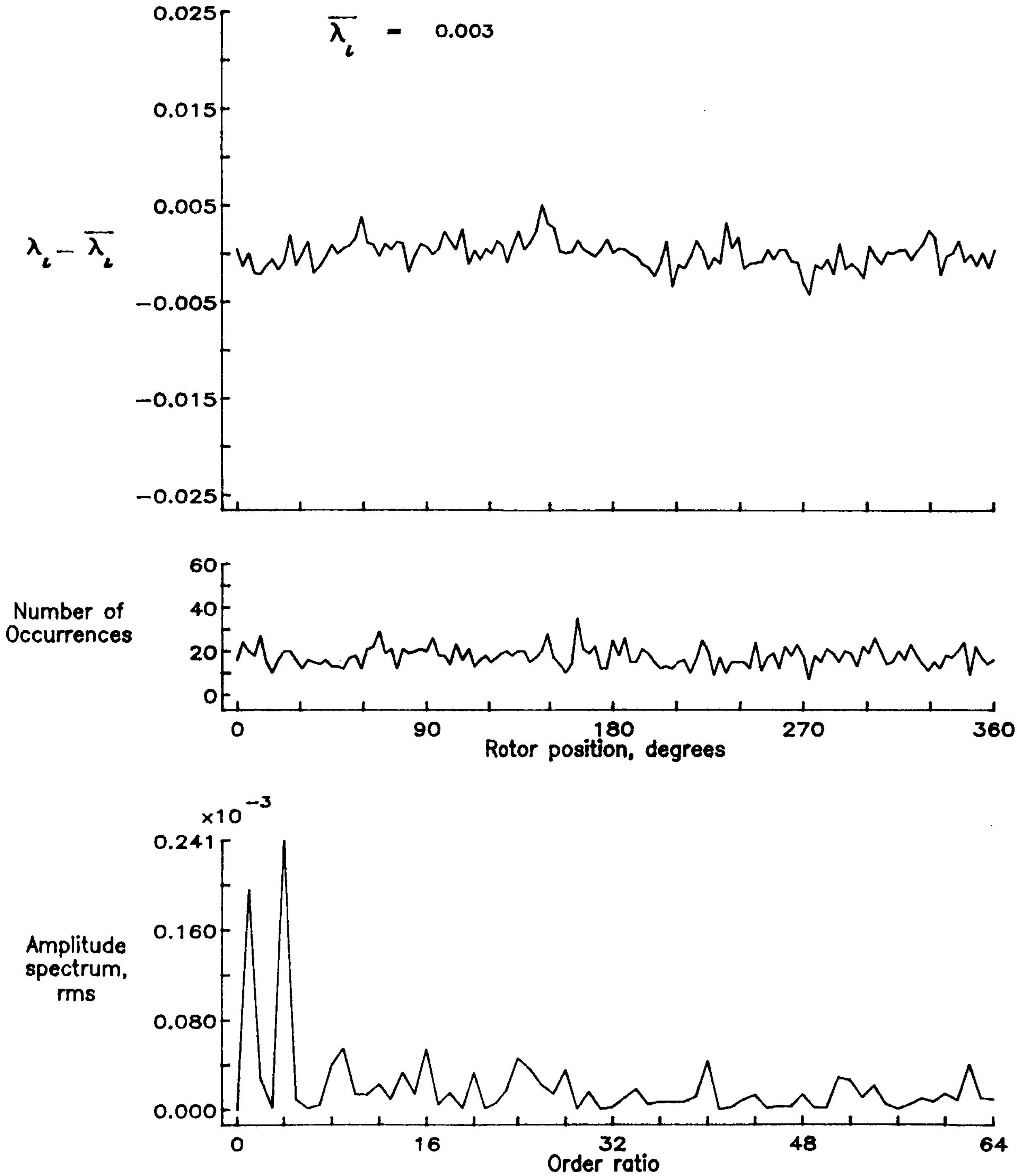


Figure 55.– Concluded.

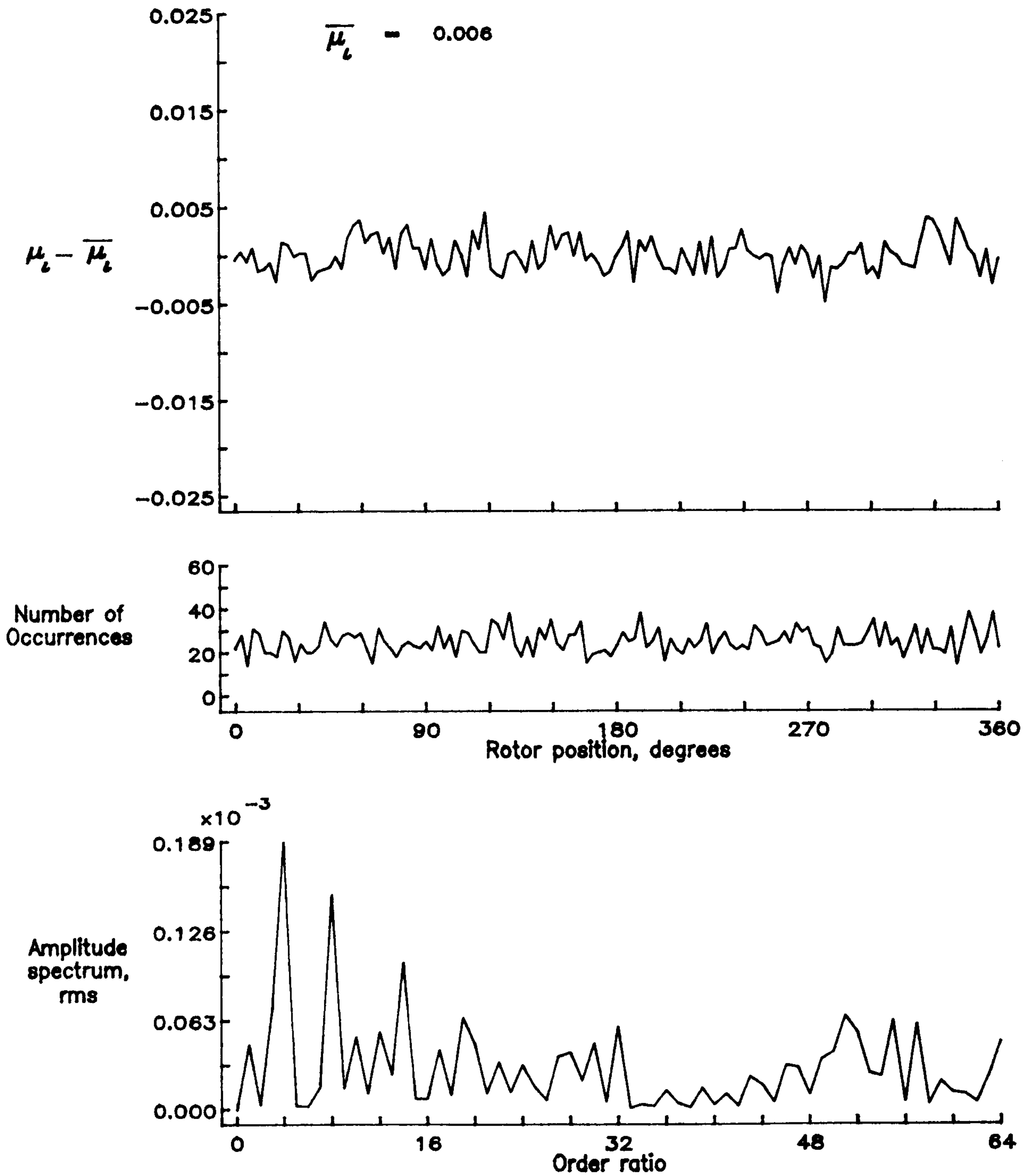


Figure 56.– Induced inflow velocity measured at 60 degrees and r/R of 1.04.

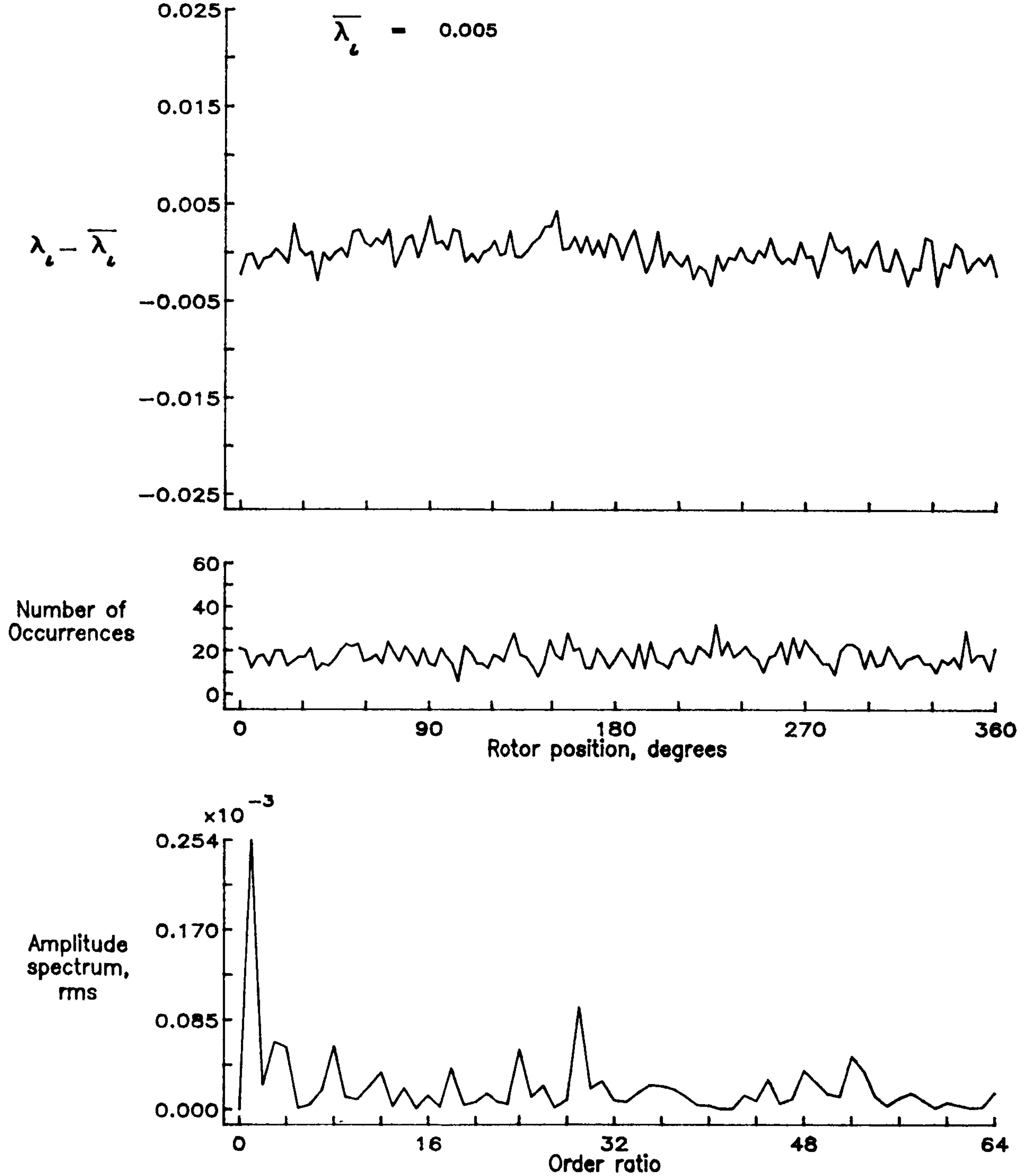


Figure 56.– Concluded.

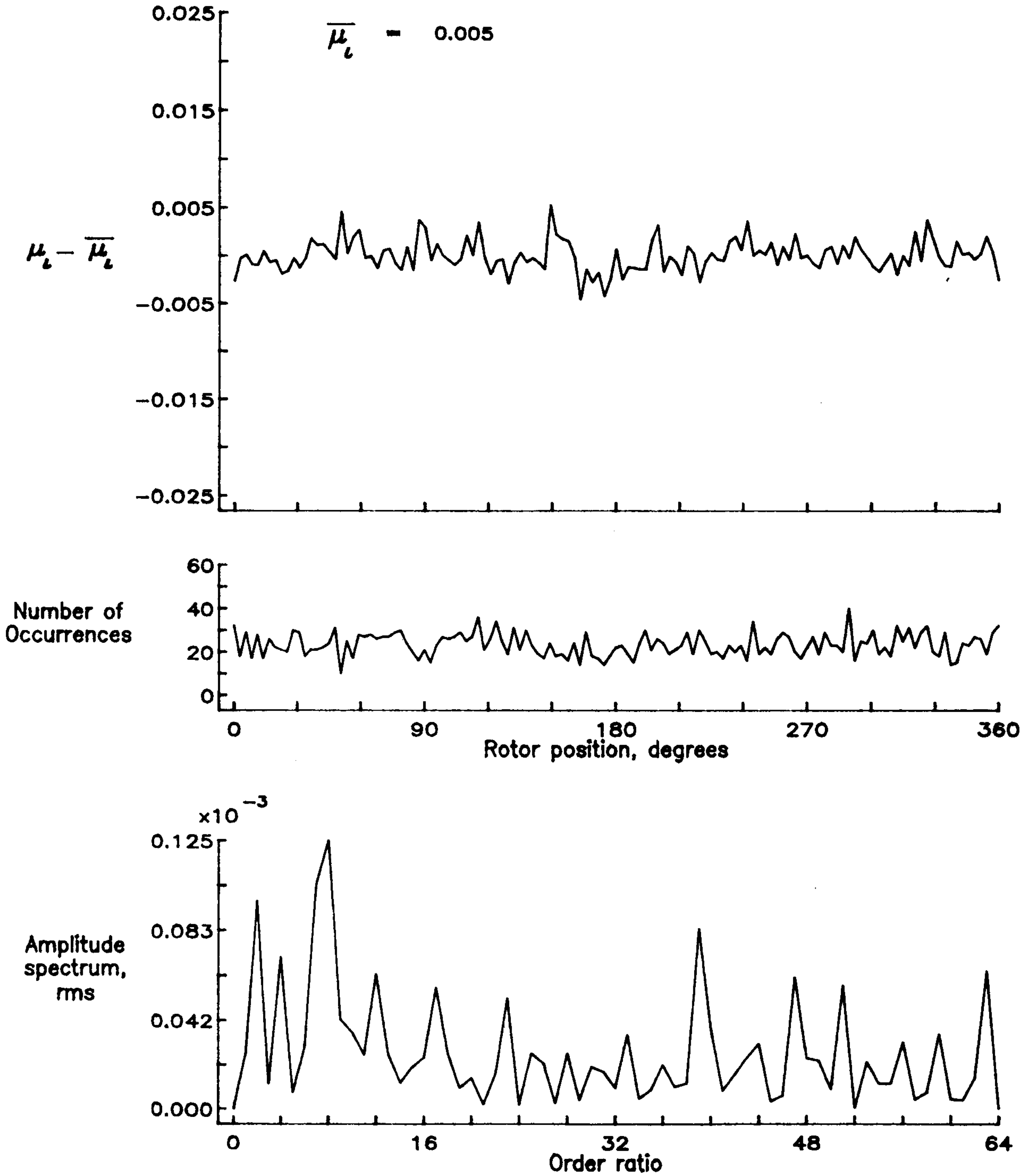
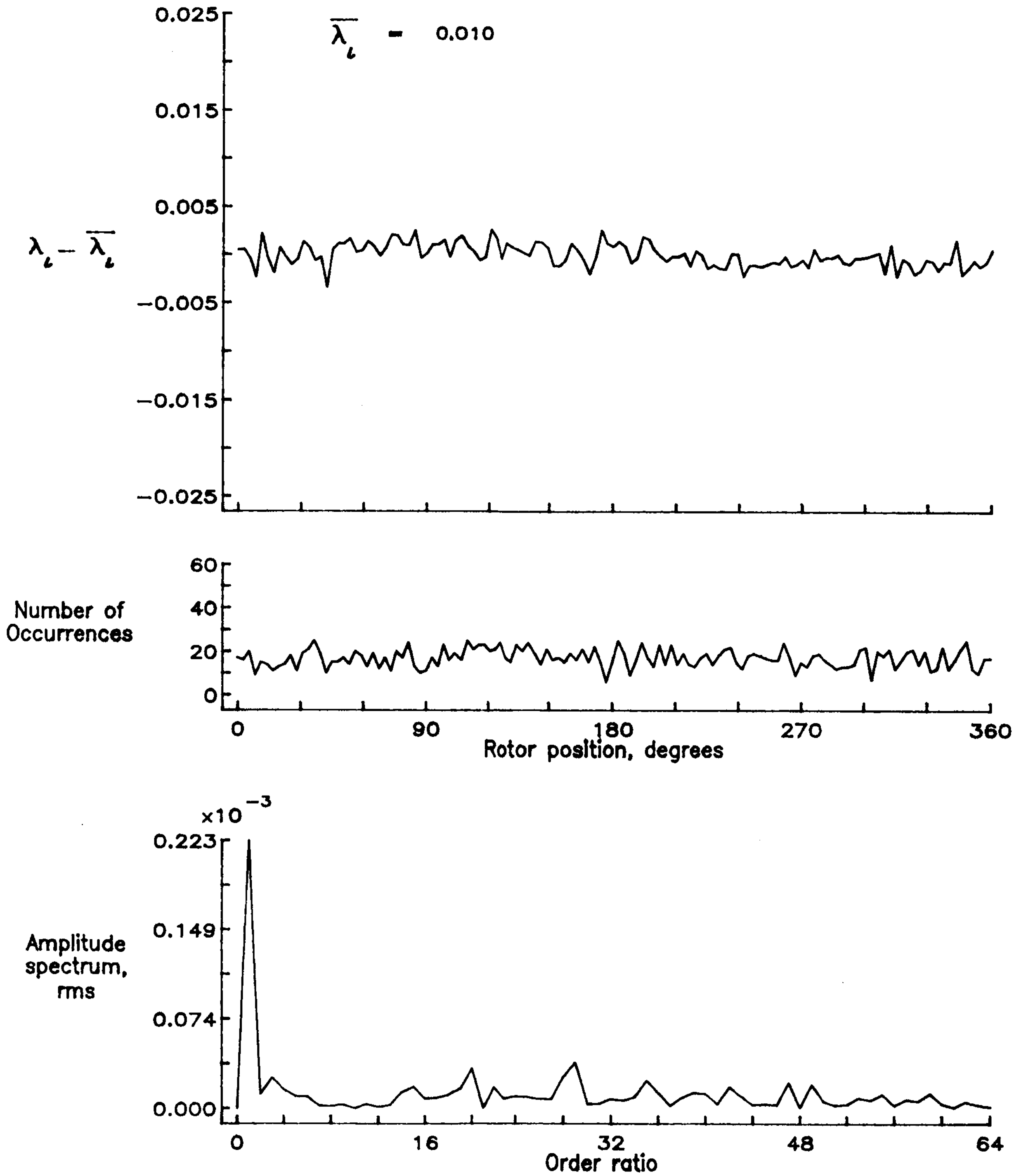


Figure 57.– Induced inflow velocity measured at 60 degrees and r/R of 1.10.



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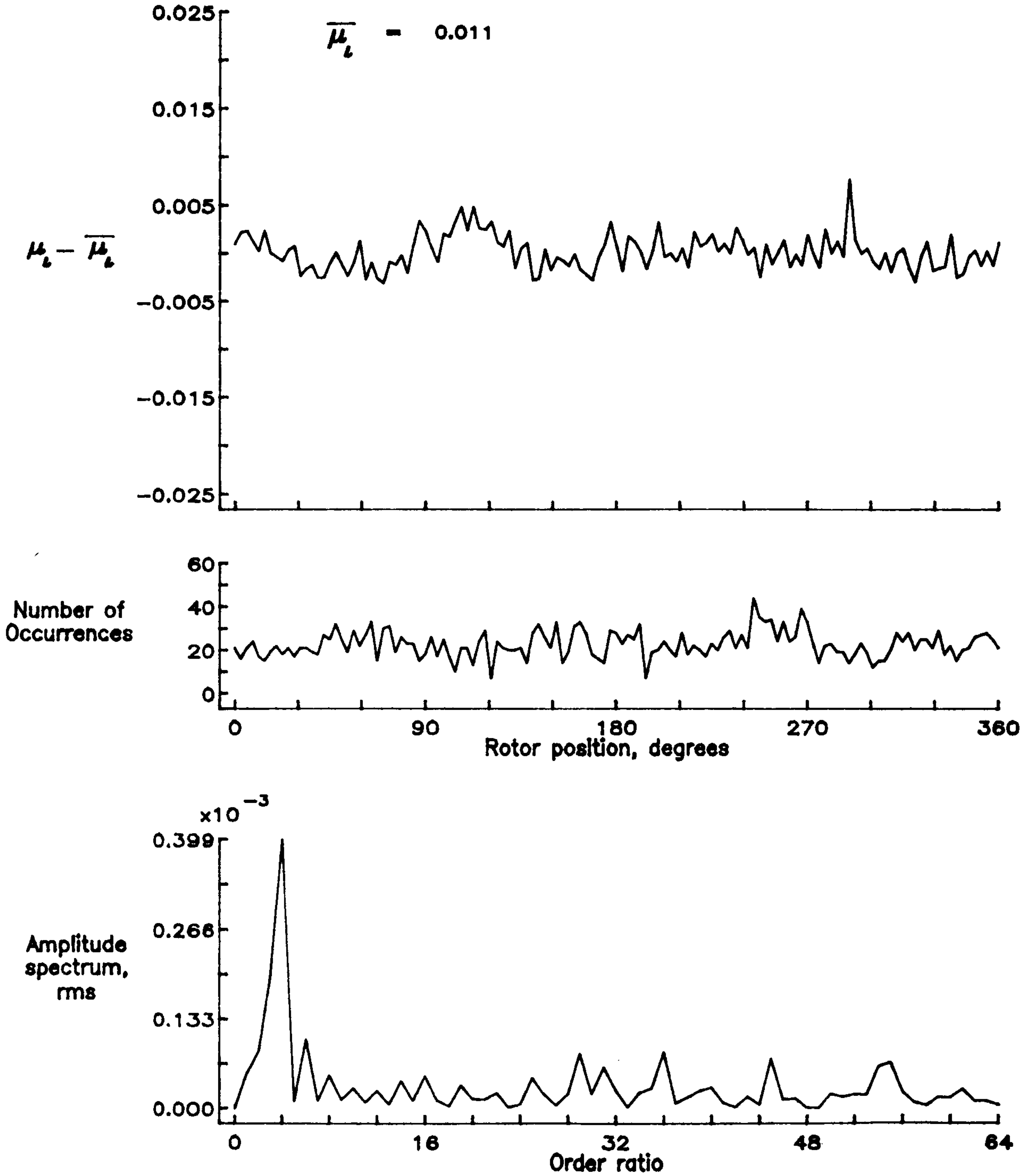
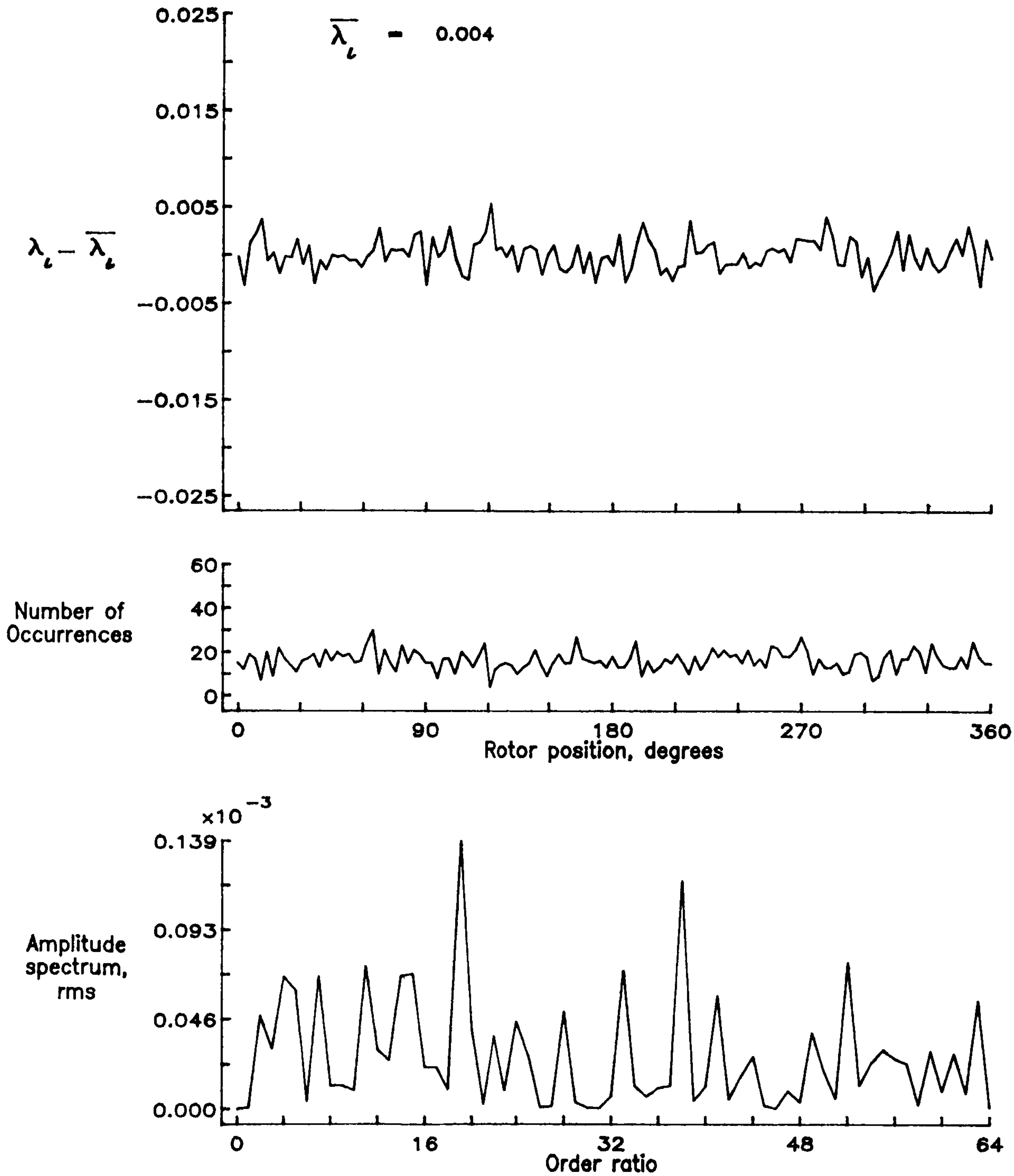


Figure 58.– Induced inflow velocity measured at 90 degrees and r/R of 0.20.



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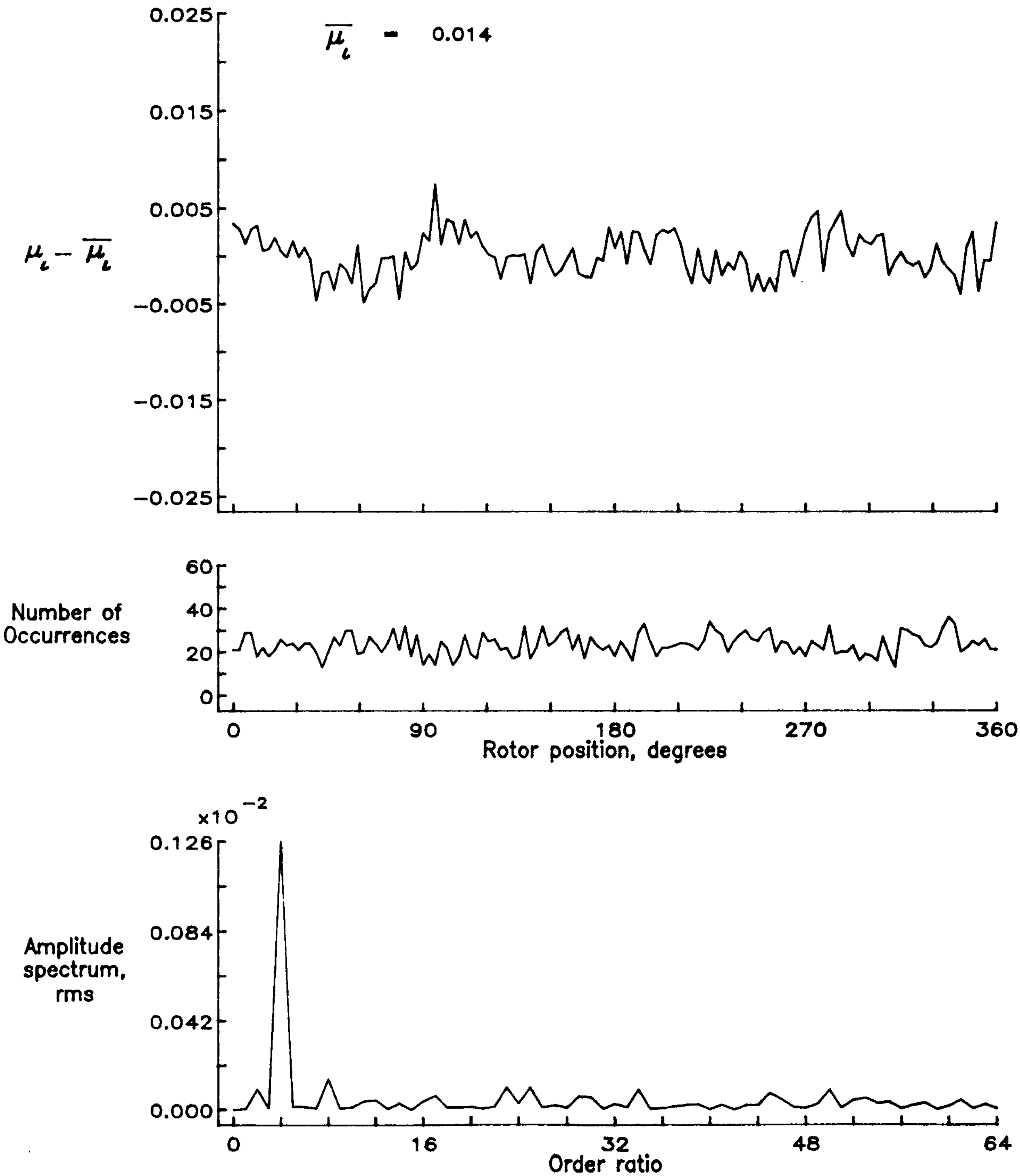
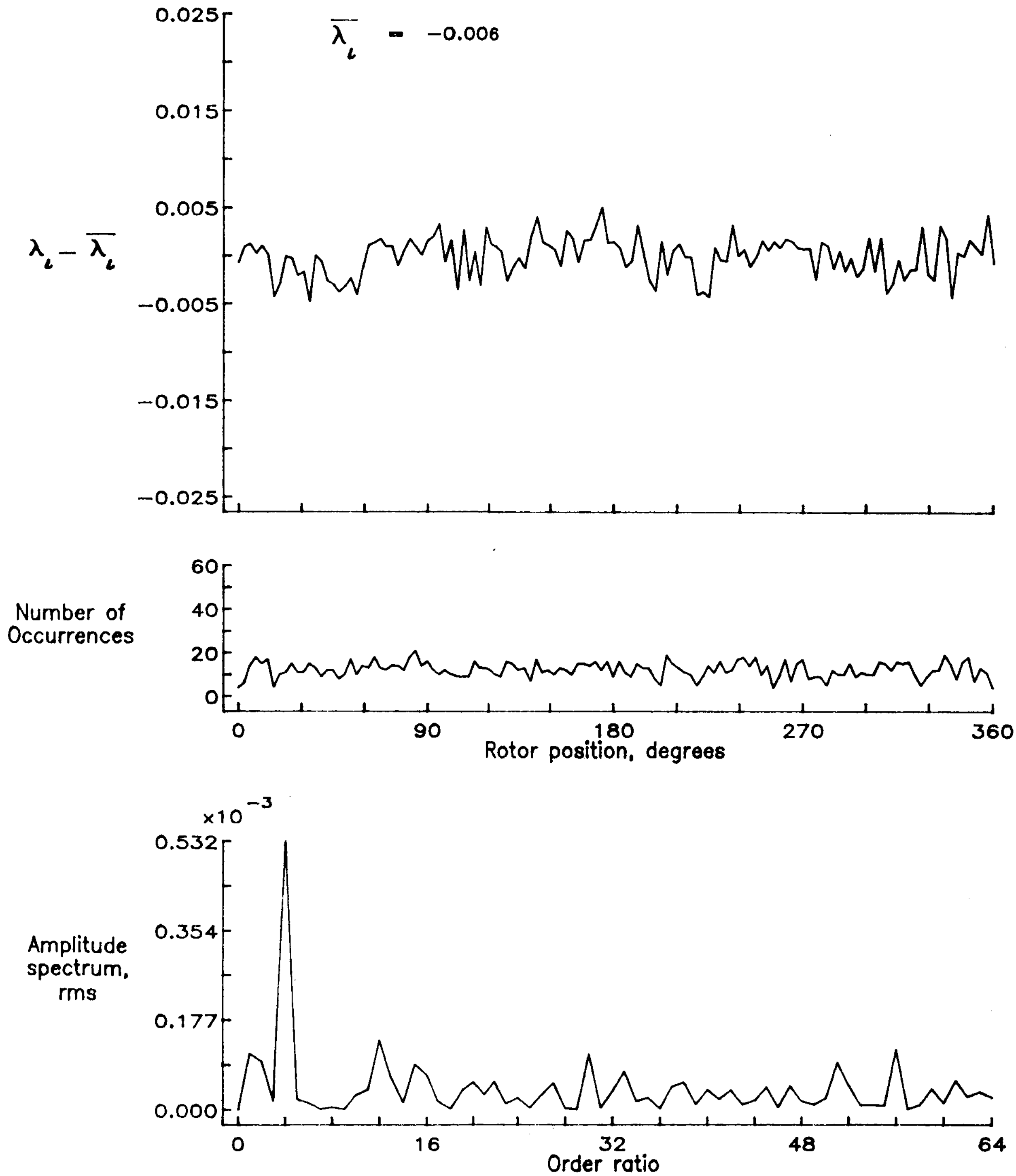


Figure 59.– Induced inflow velocity measured at 90 degrees and r/R of 0.40.



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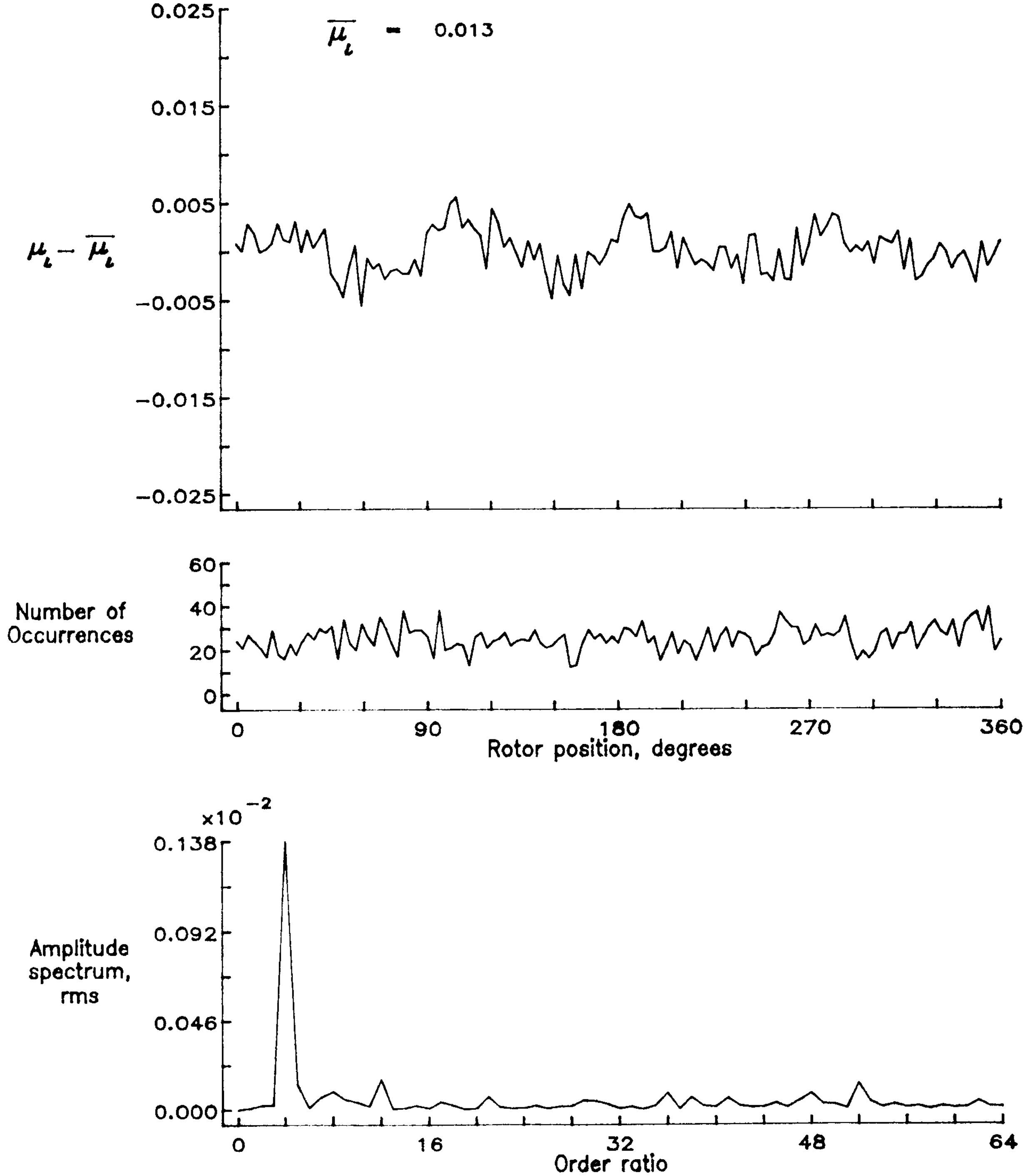
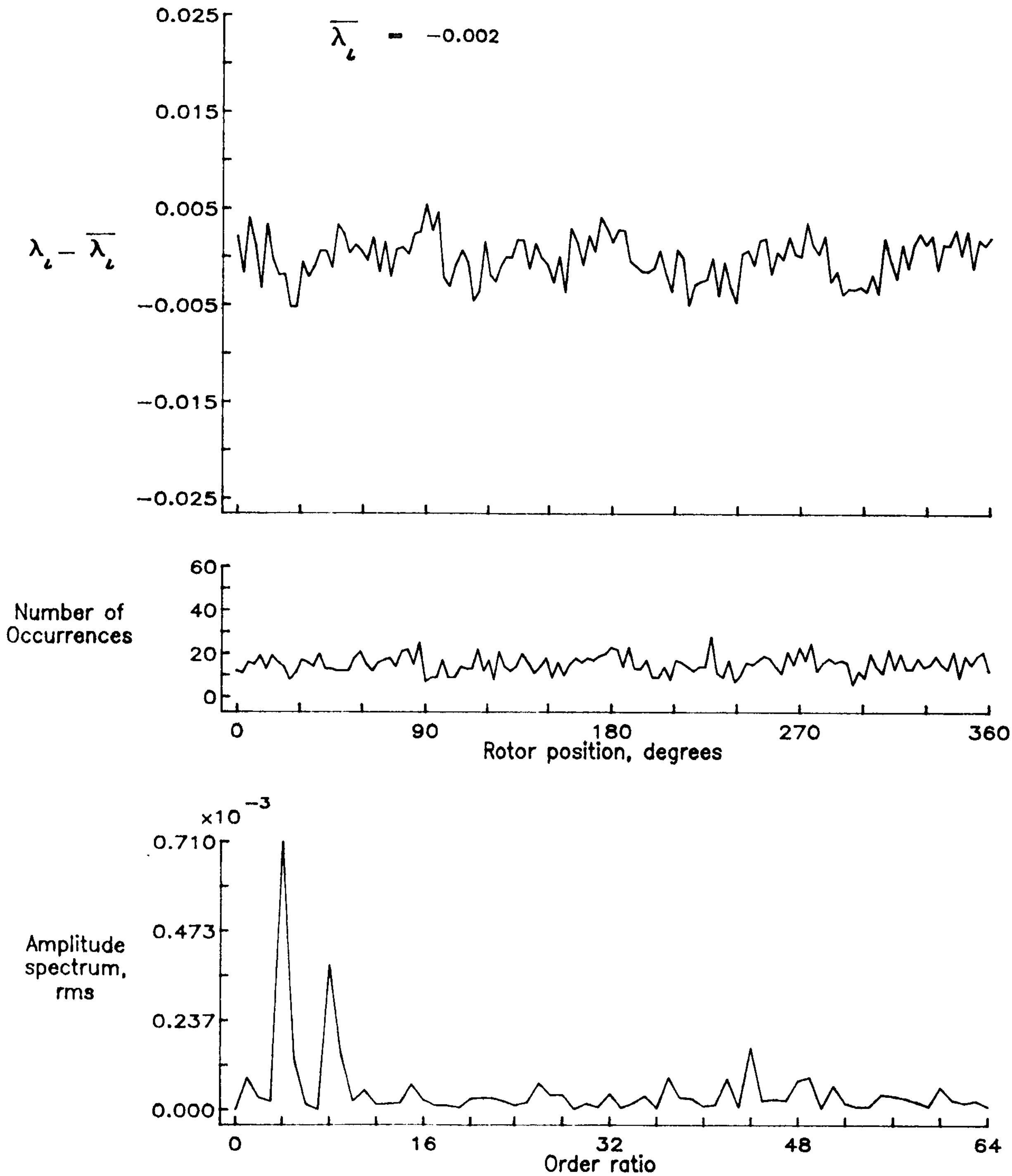


Figure 60.– Induced inflow velocity measured at 90 degrees and r/R of 0.50.



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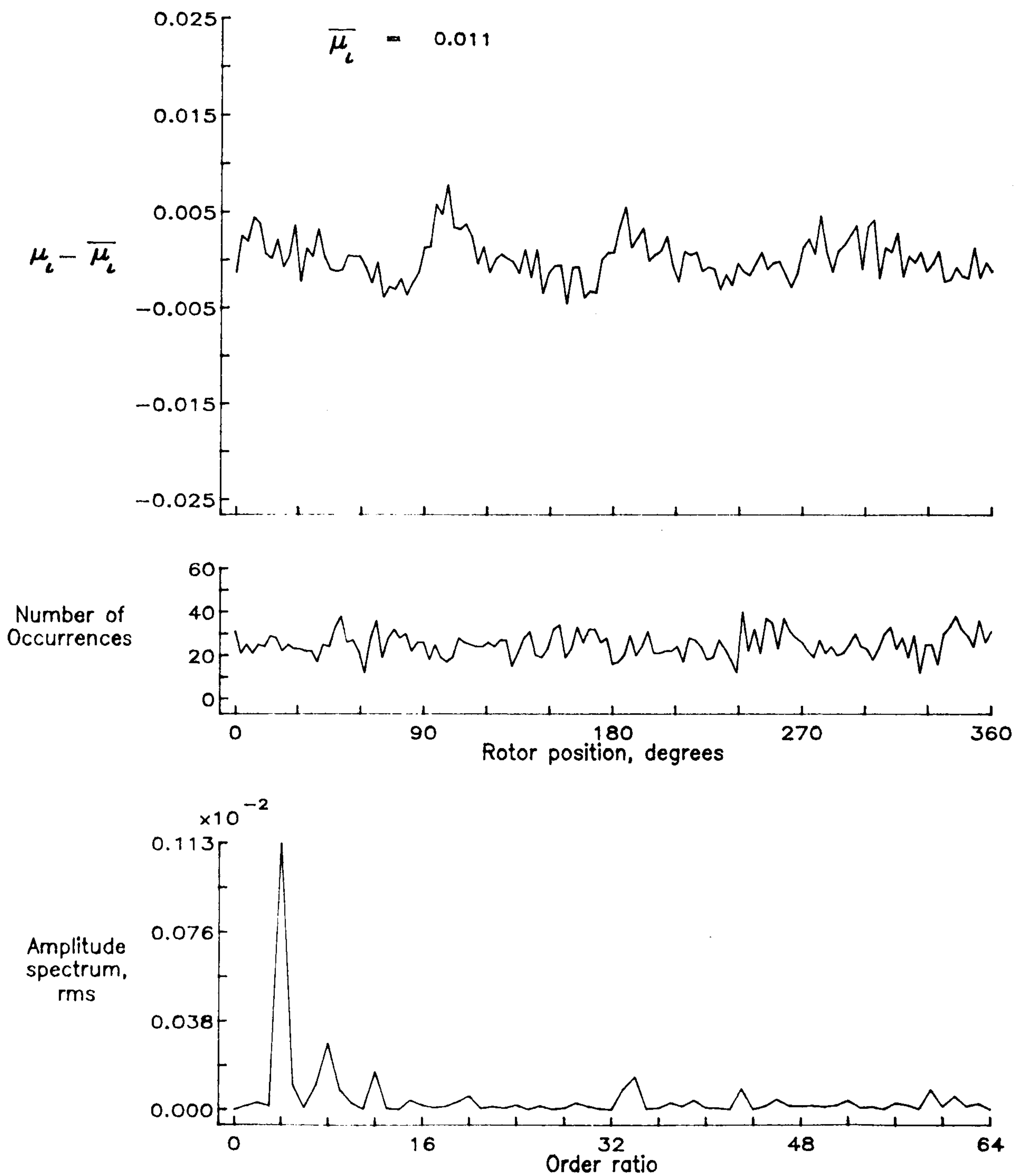
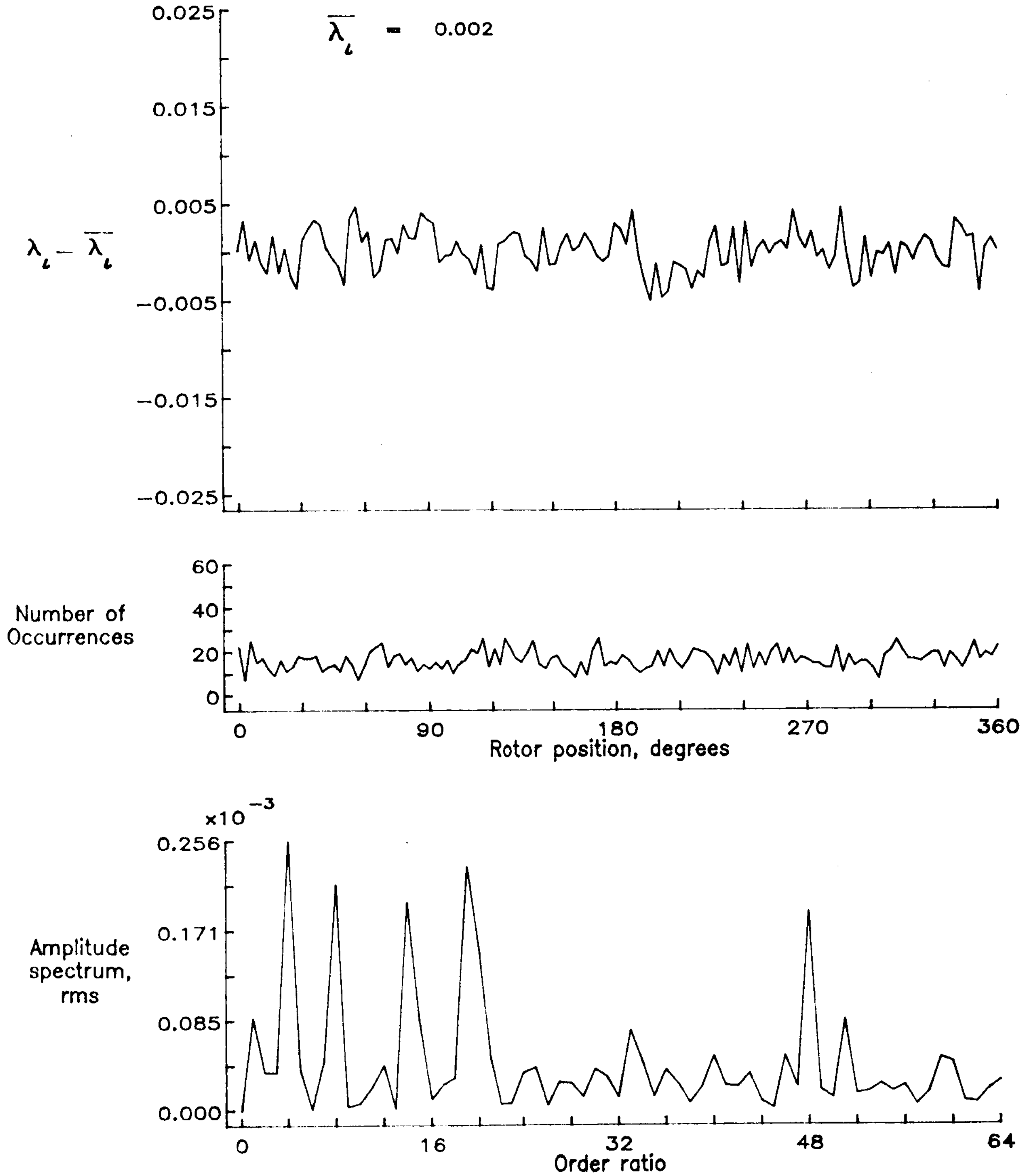


Figure 61.– Induced inflow velocity measured at 90 degrees and r/R of 0.60.



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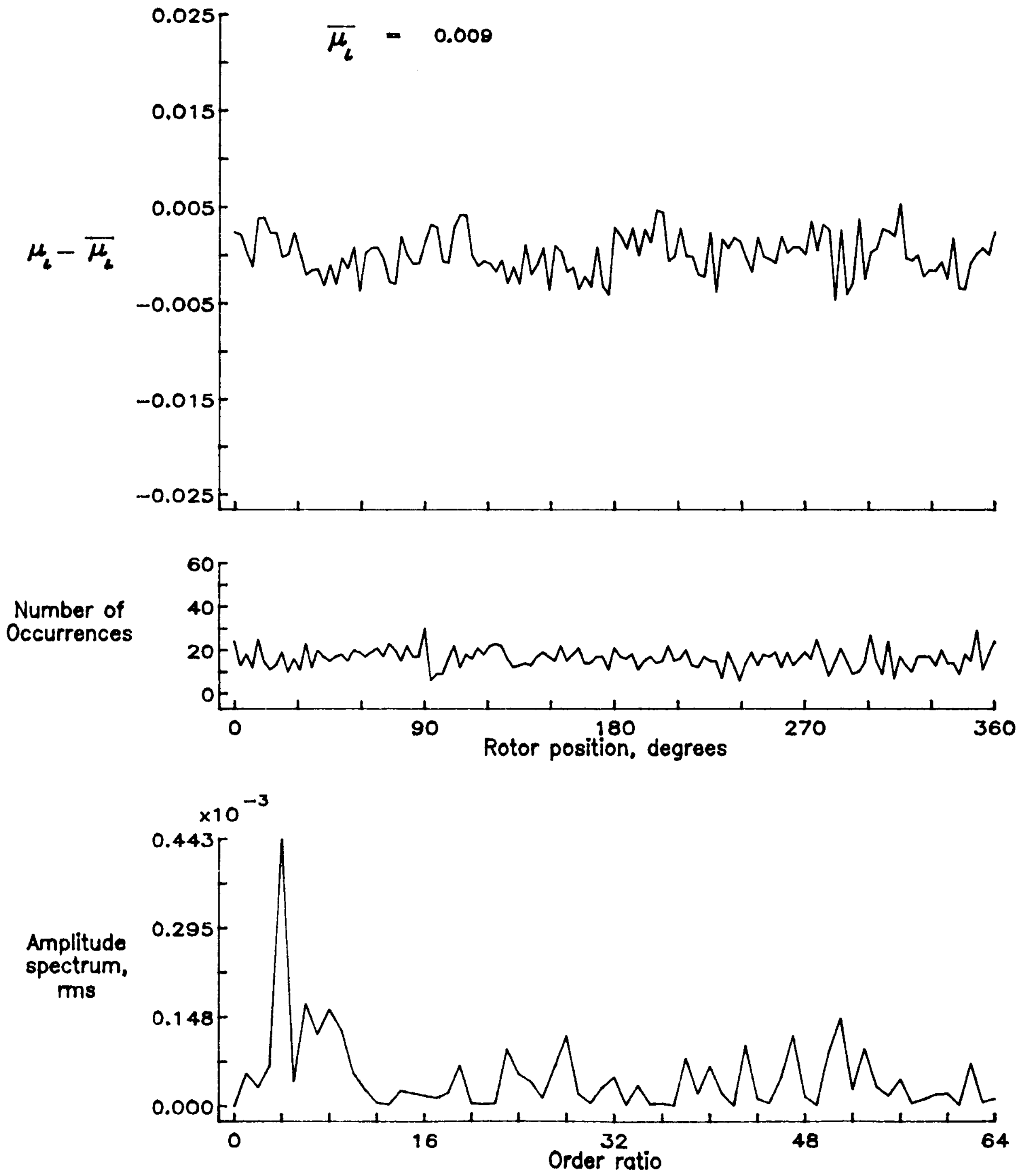
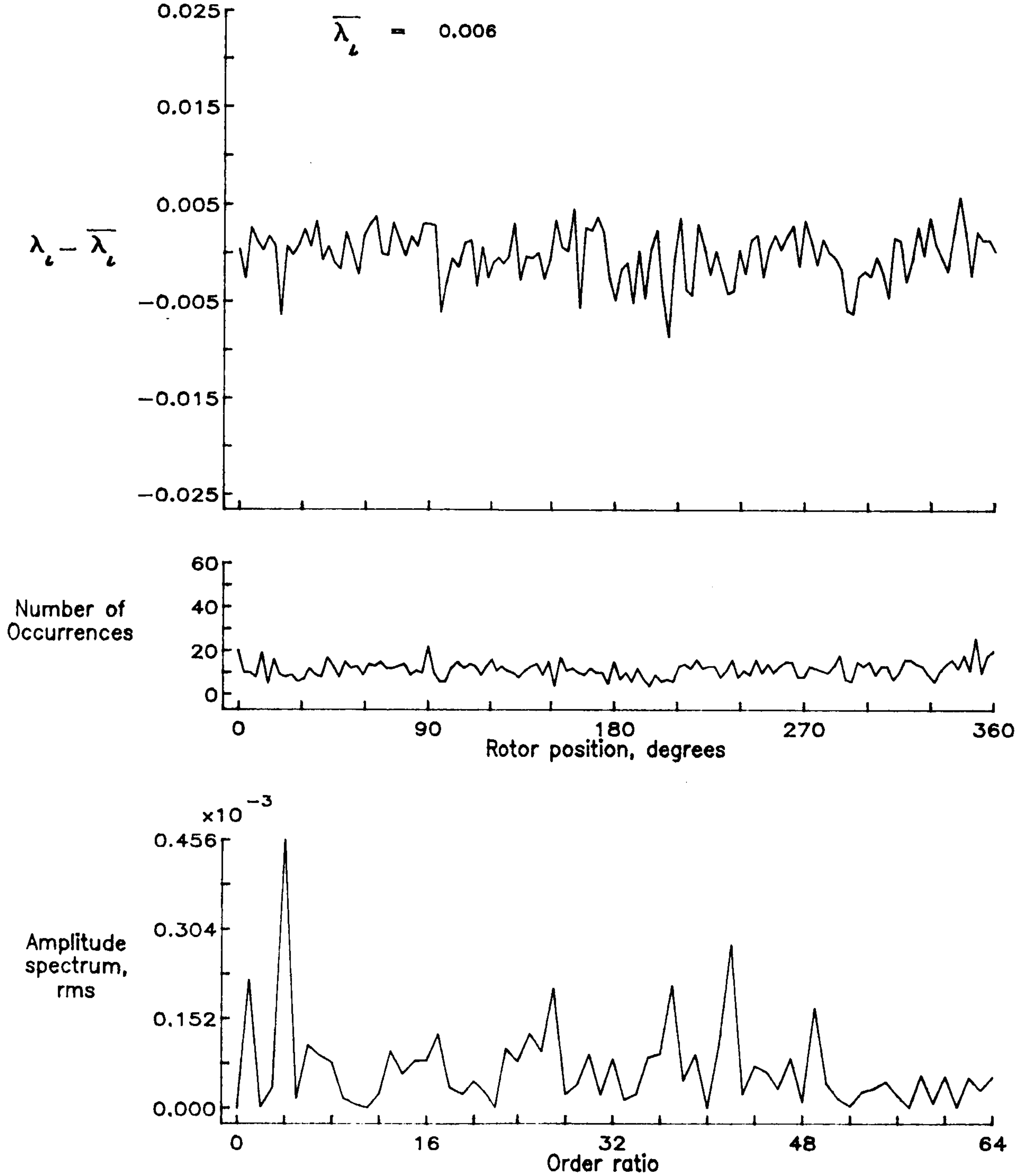


Figure 62.– Induced inflow velocity measured at 90 degrees and r/R of 0.70.



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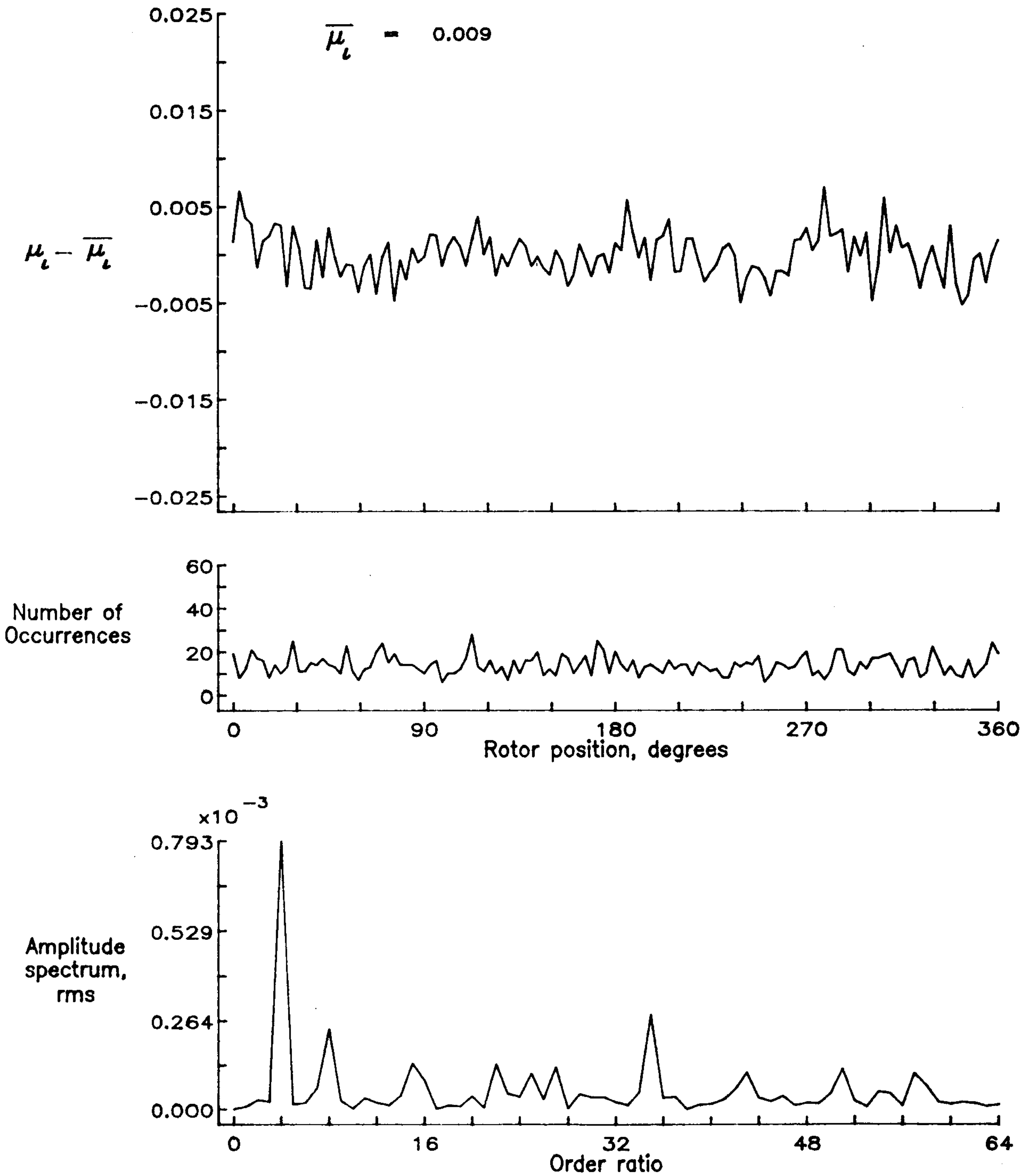
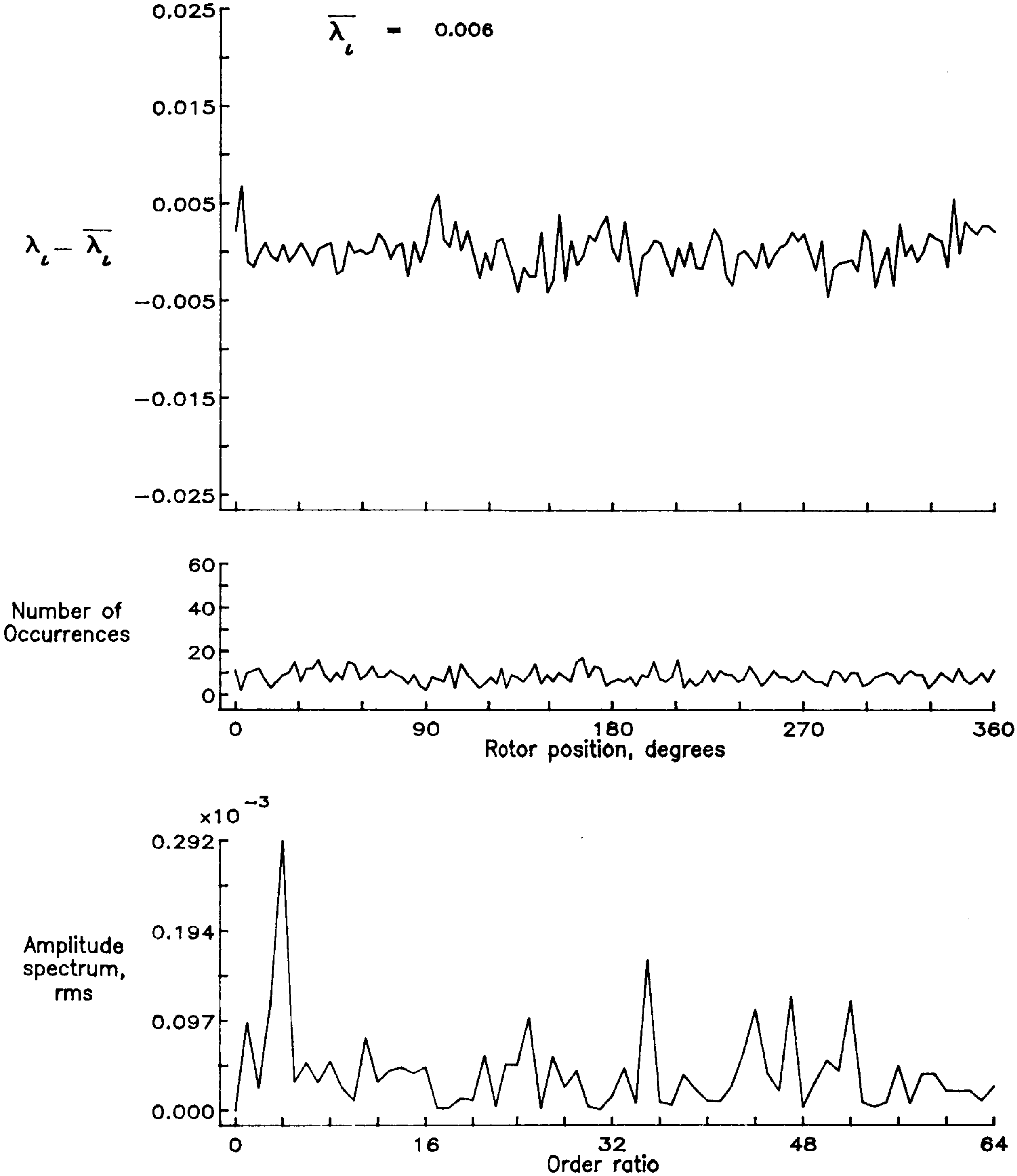


Figure 63.– Induced inflow velocity measured at 90 degrees and r/R of 0.74.



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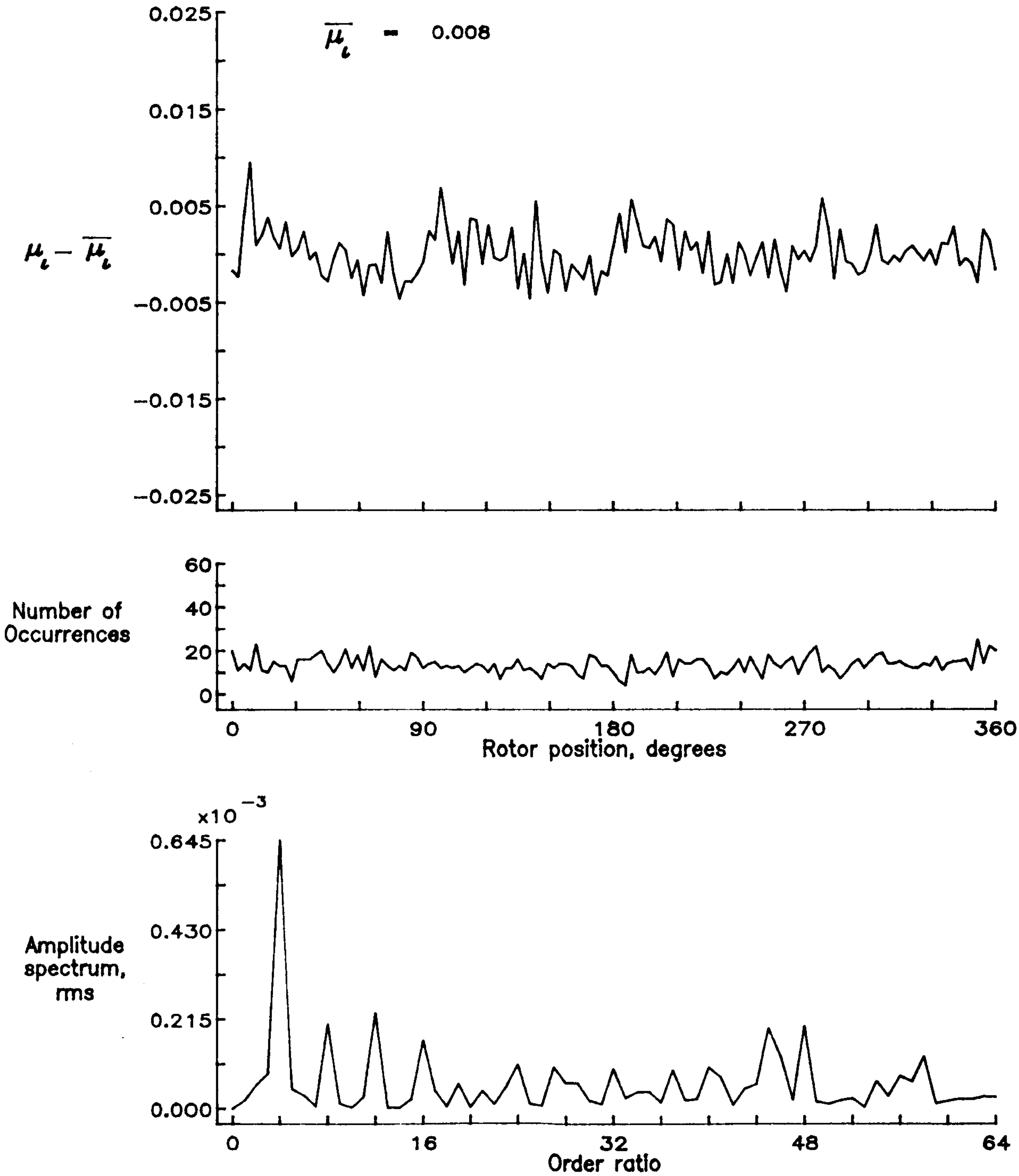


Figure 64.– Induced inflow velocity measured at 90 degrees and r/R of 0.78.

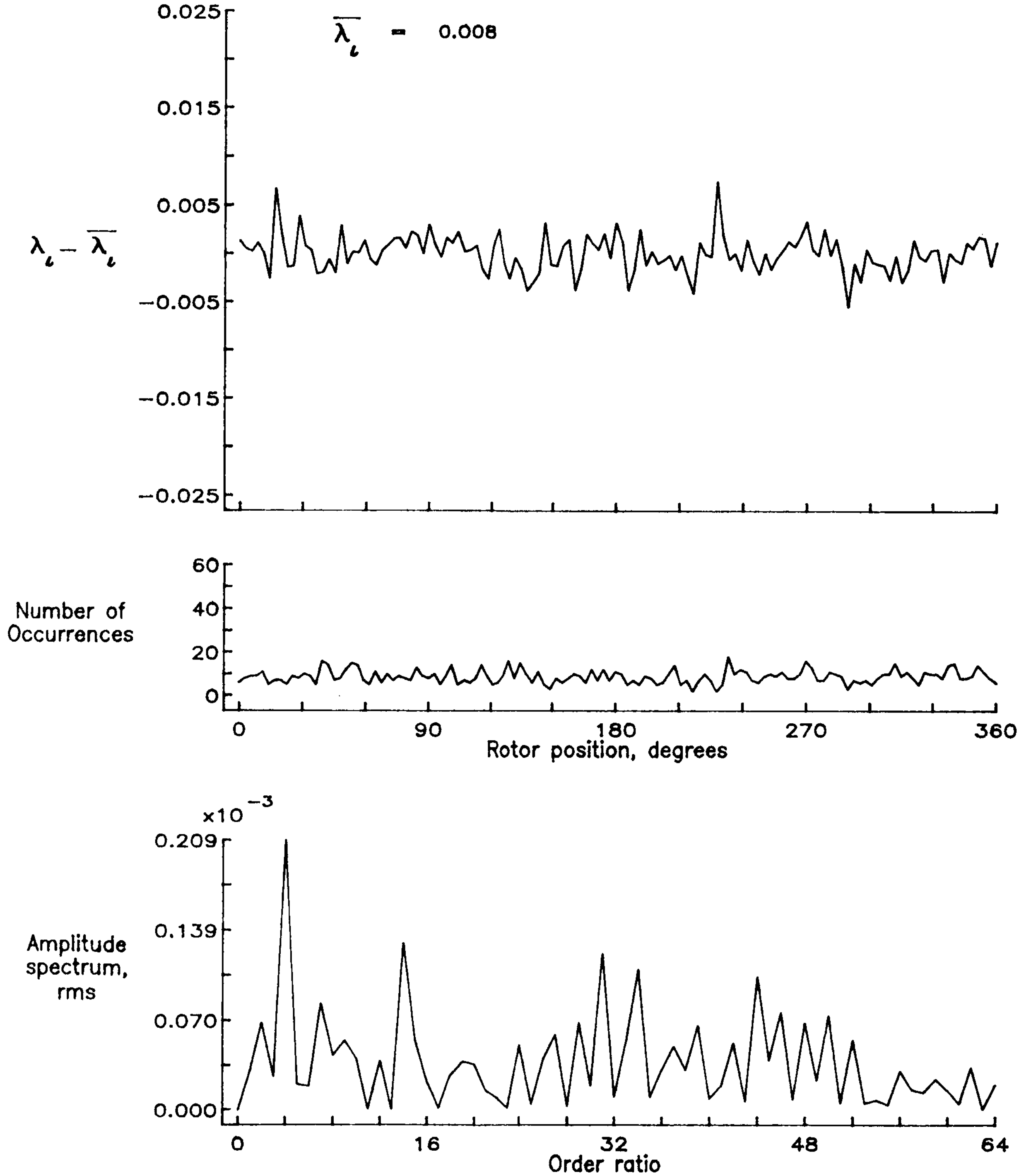


Figure 64.– Concluded.

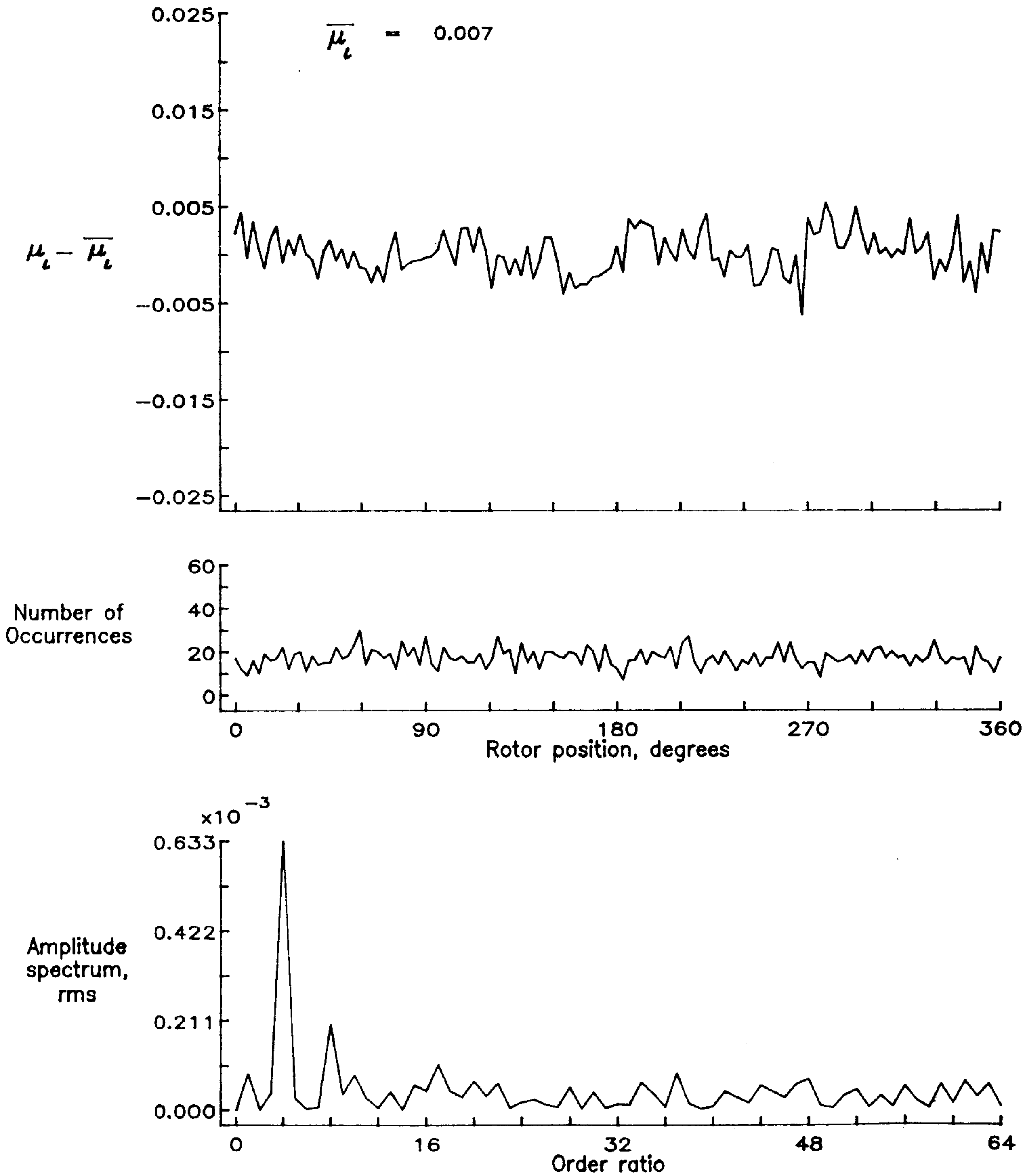


Figure 65.– Induced inflow velocity measured at 90 degrees and r/R of 0.82.

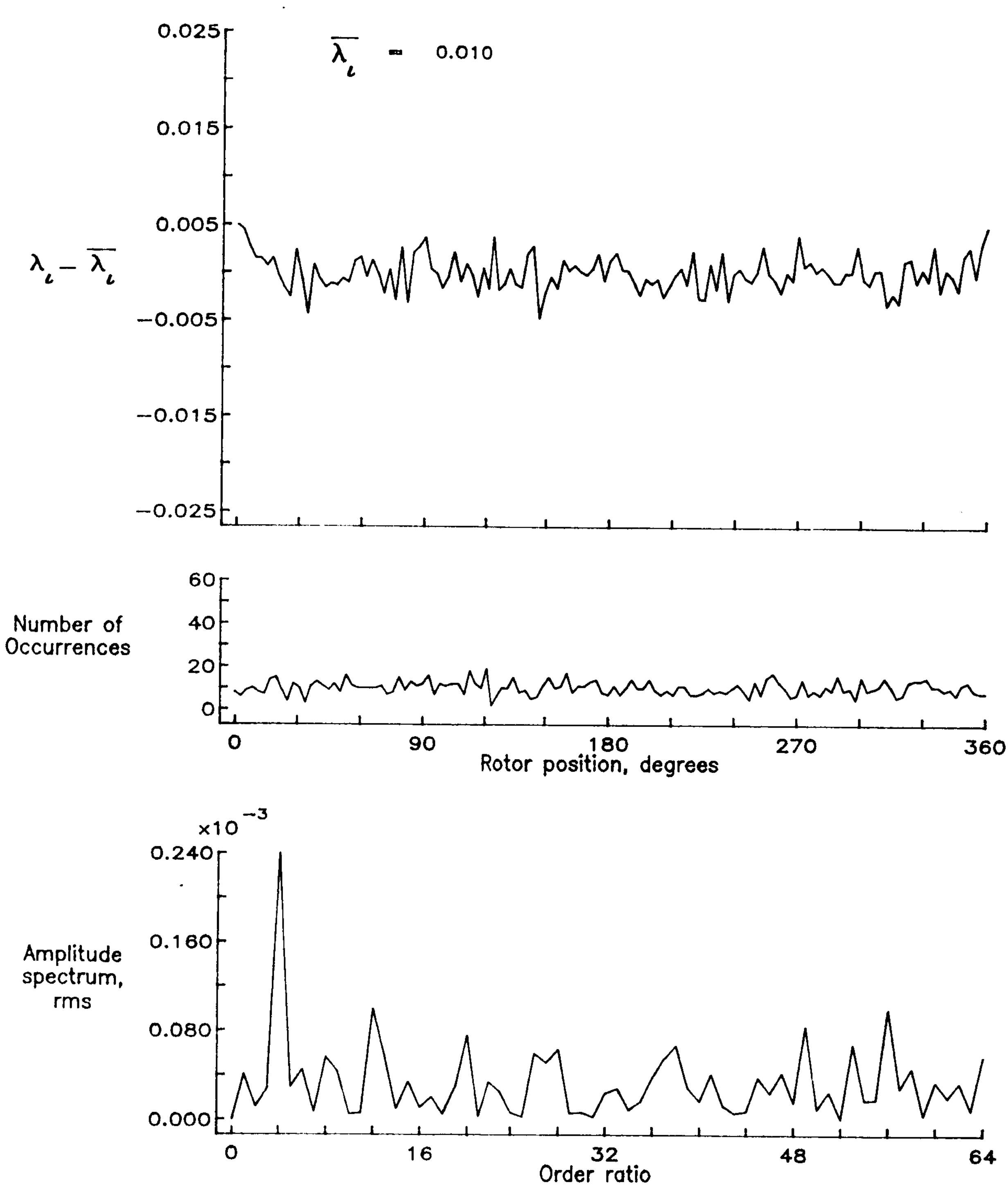


Figure 65.– Concluded.

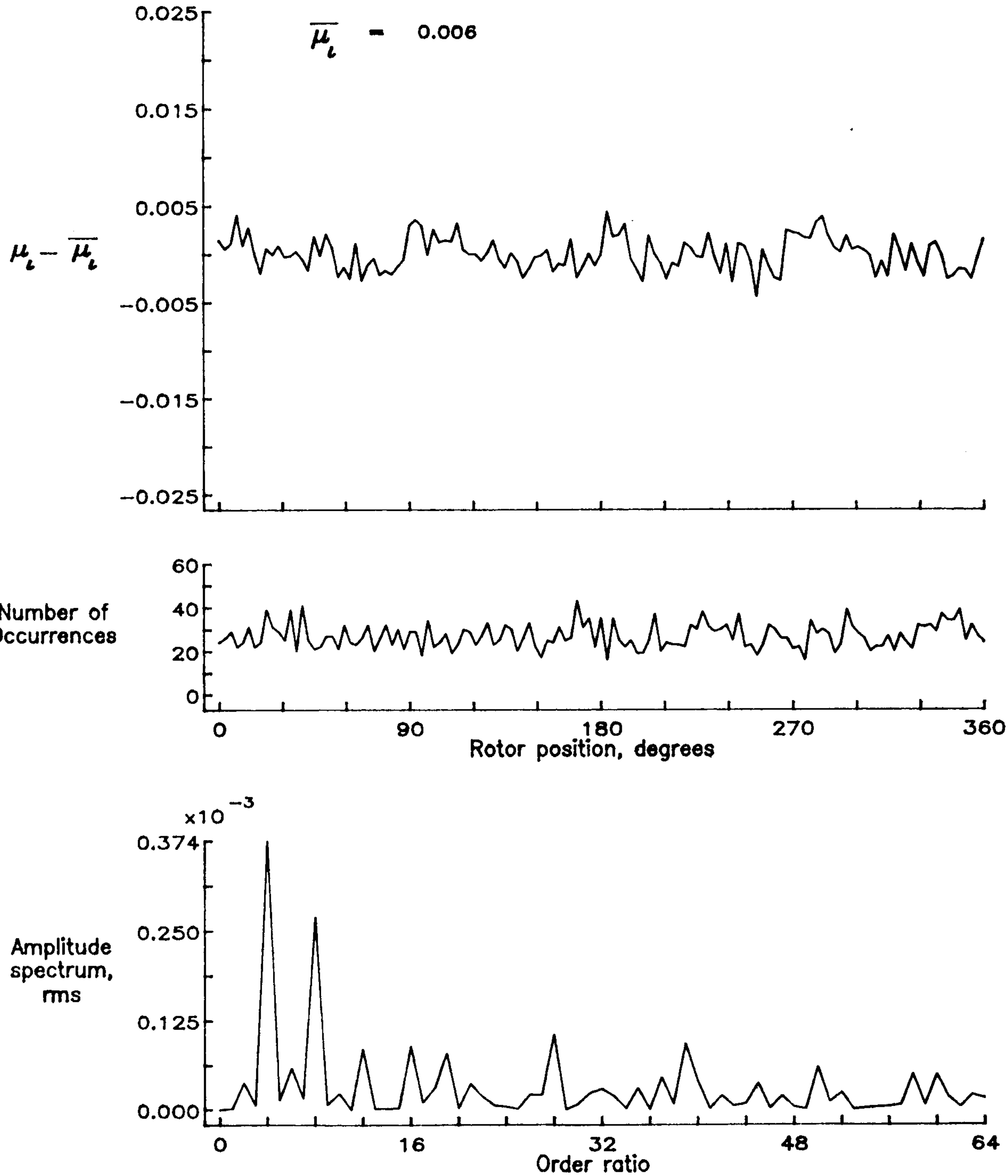
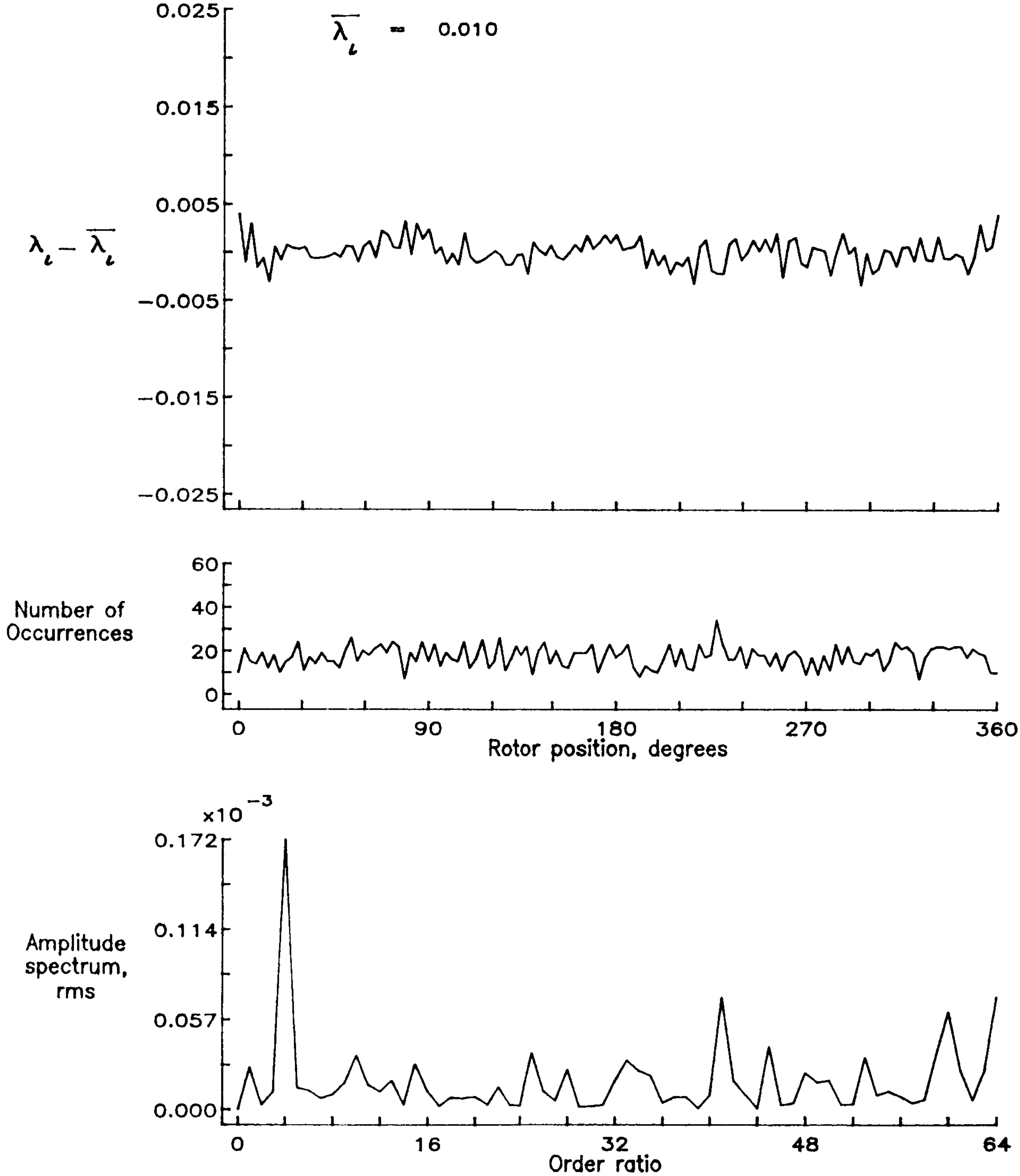


Figure 66.– Induced inflow velocity measured at 90 degrees and r/R of 0.86.



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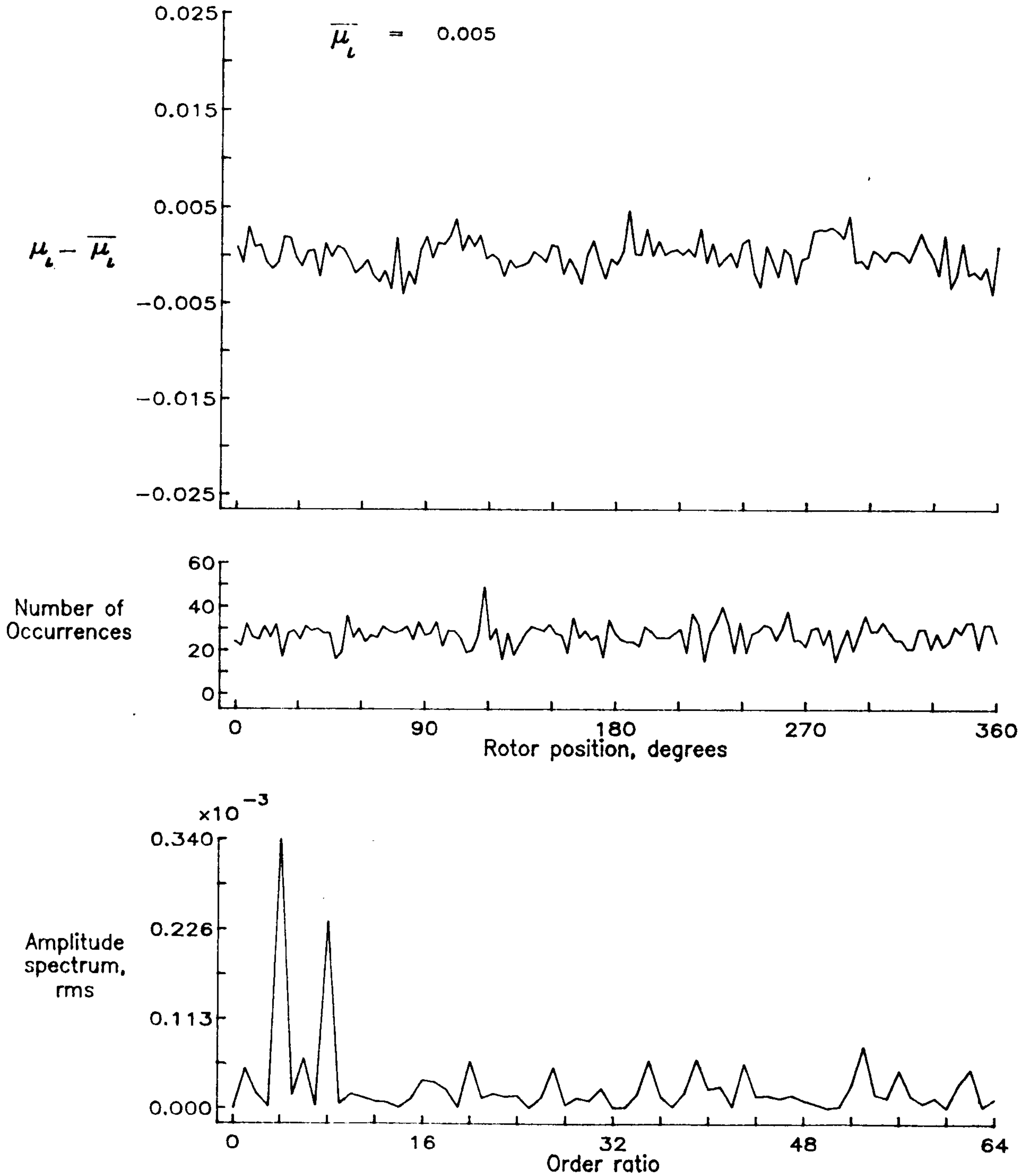


Figure 67.— Induced inflow velocity measured at 90 degrees and r/R of 0.90.

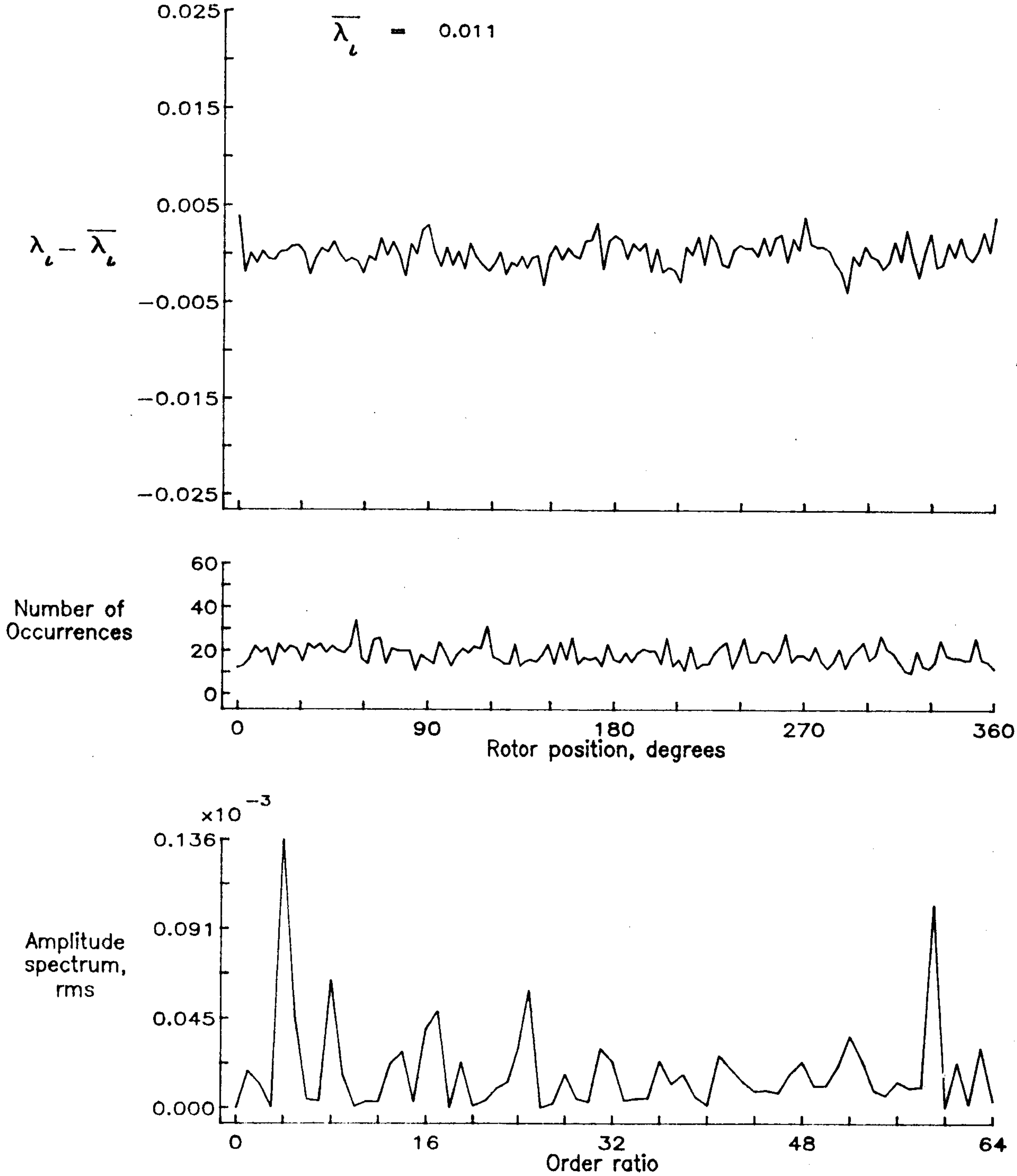


Figure 67.– Concluded.

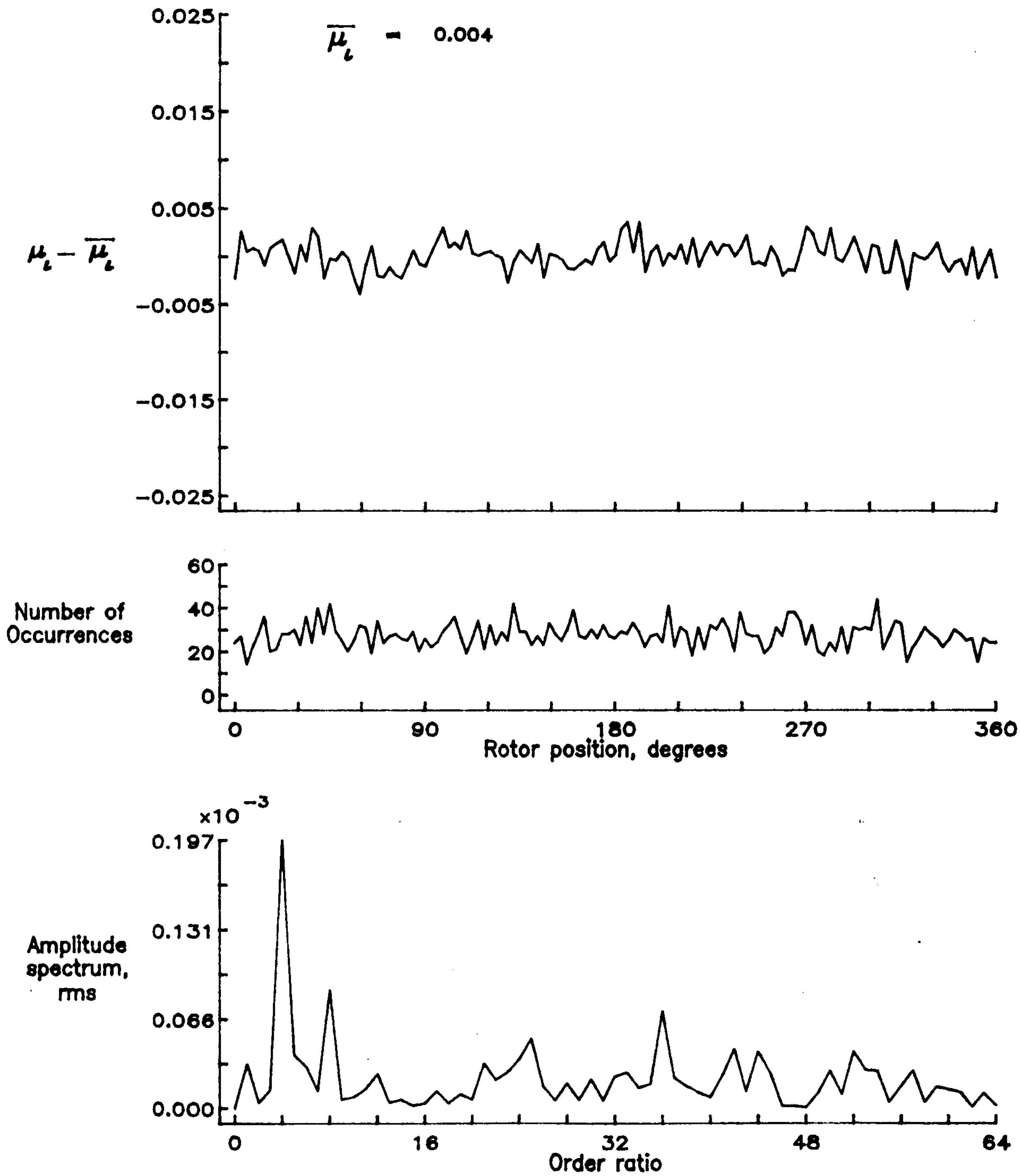
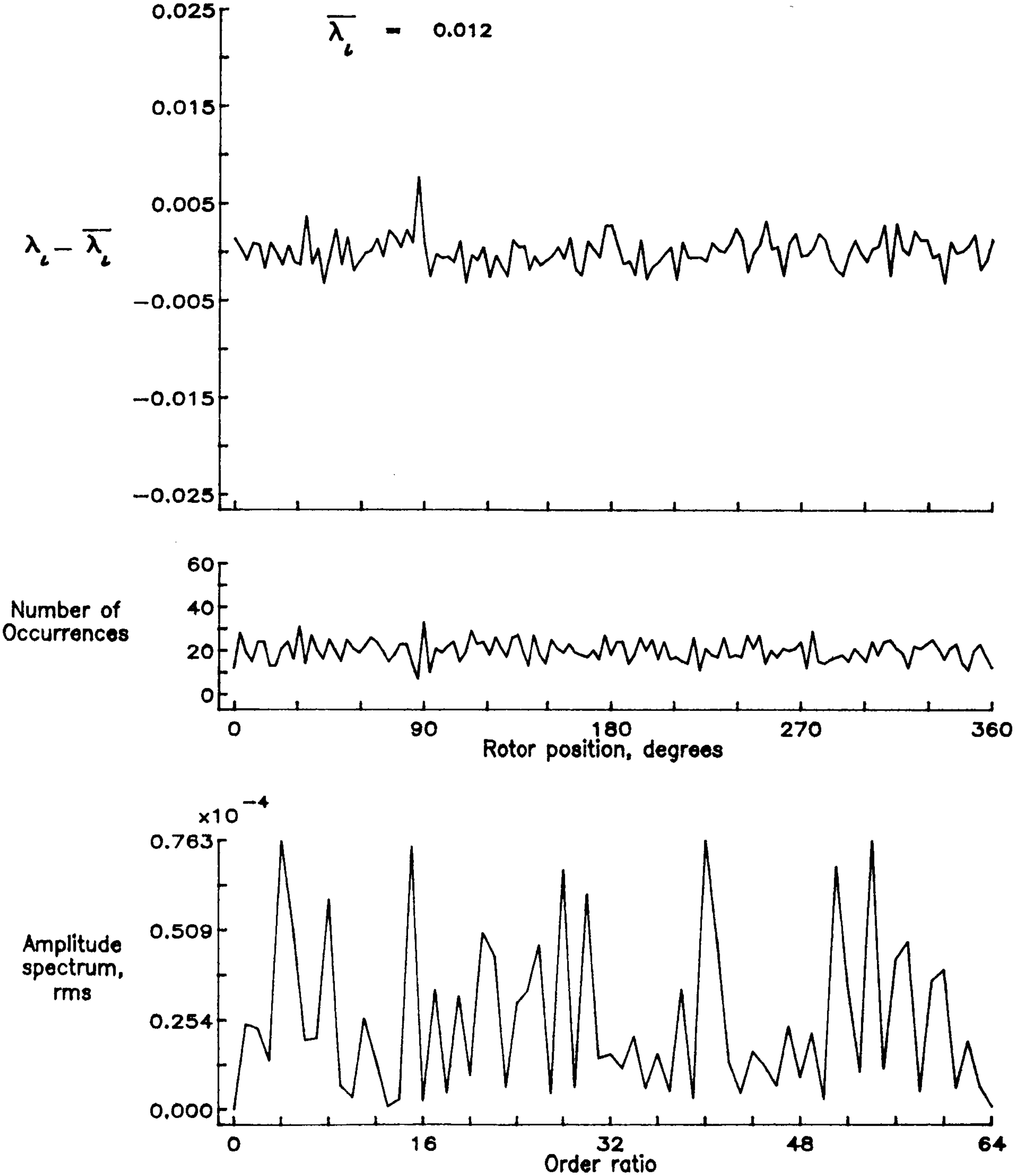


Figure 68.– Induced inflow velocity measured at 90 degrees and r/R of 0.94.



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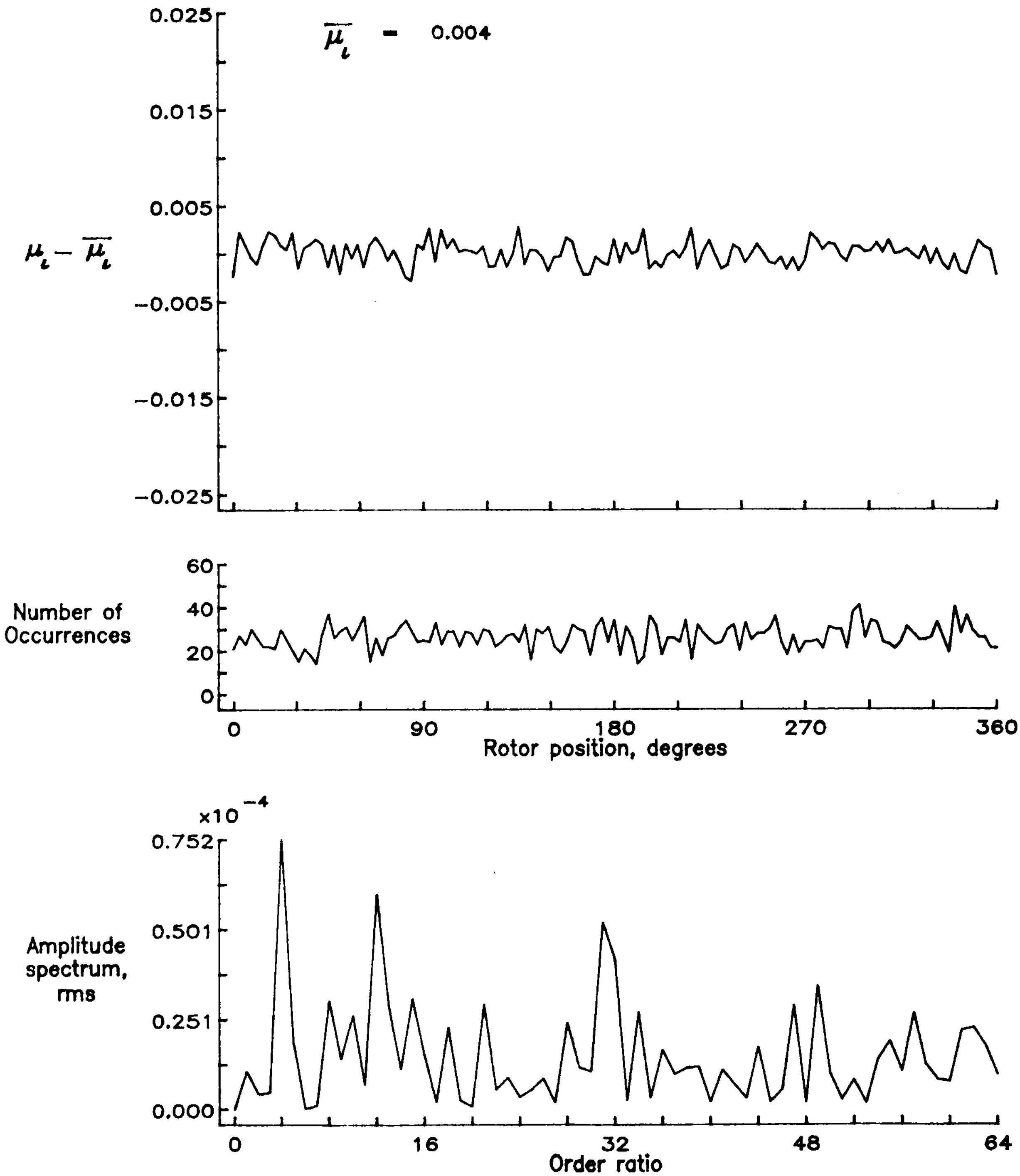


Figure 69.– Induced inflow velocity measured at 90 degrees and r/R of 0.98.

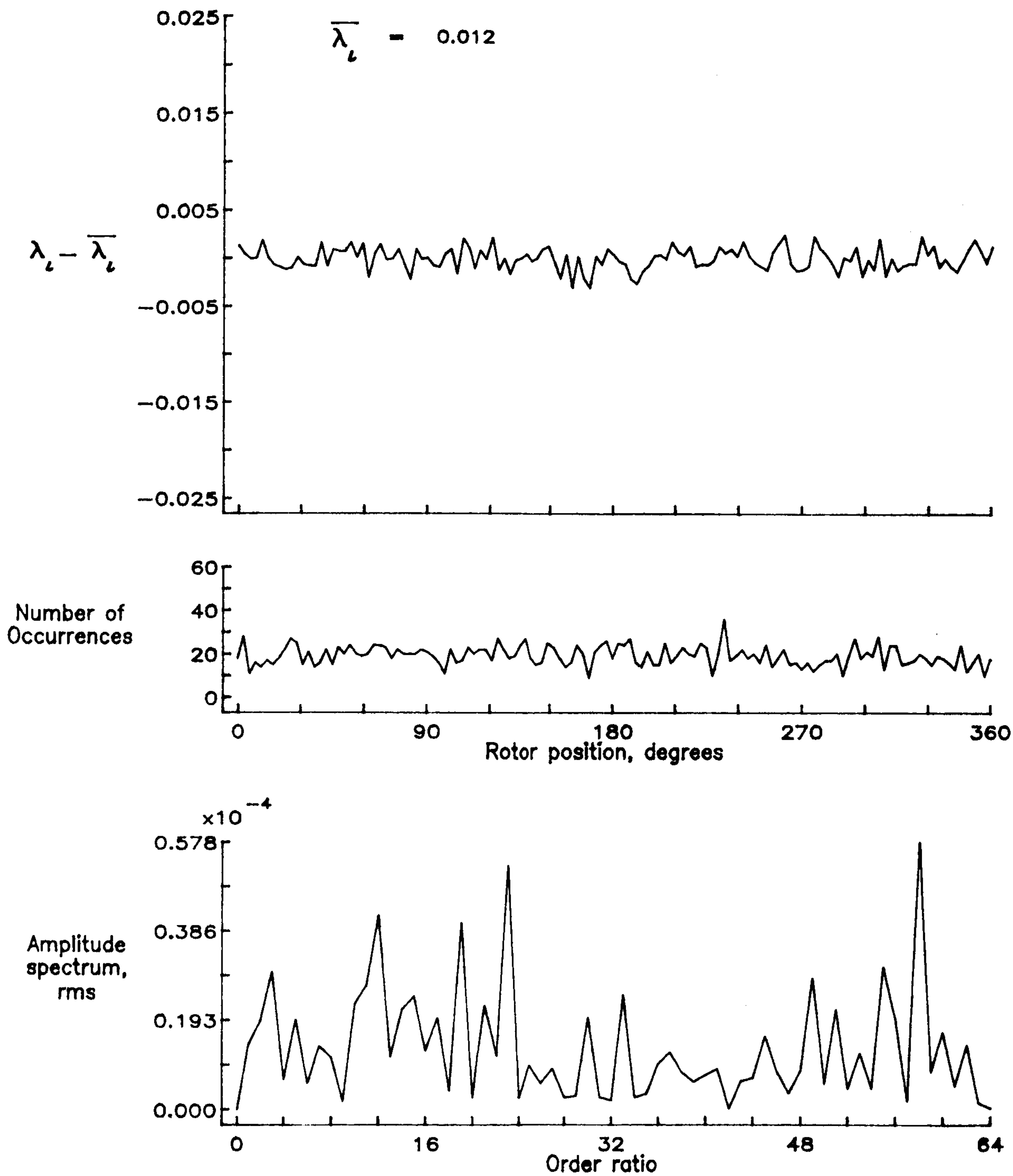


Figure 69.— Concluded.

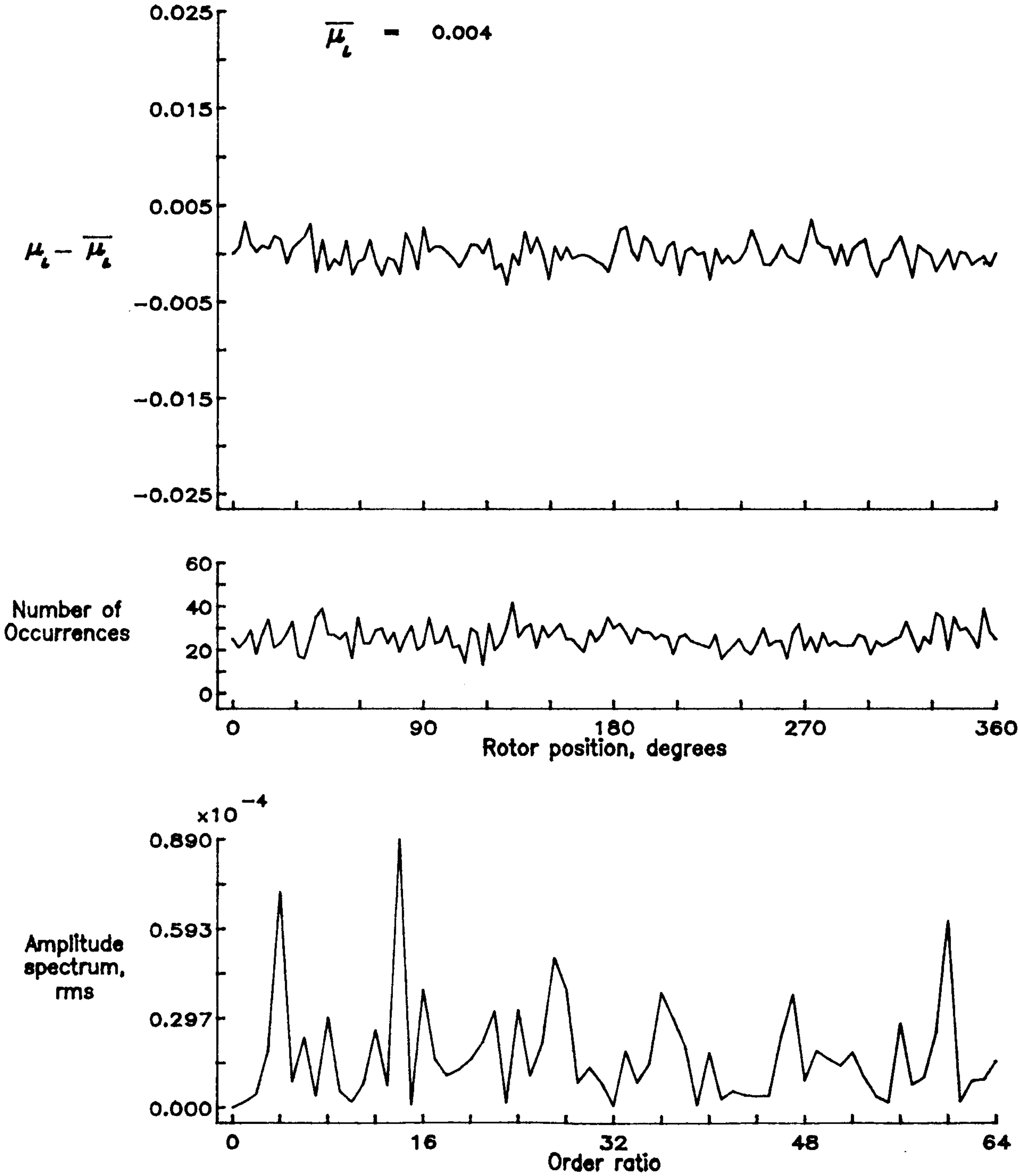


Figure 70.– Induced inflow velocity measured at 90 degrees and r/R of 1.02.

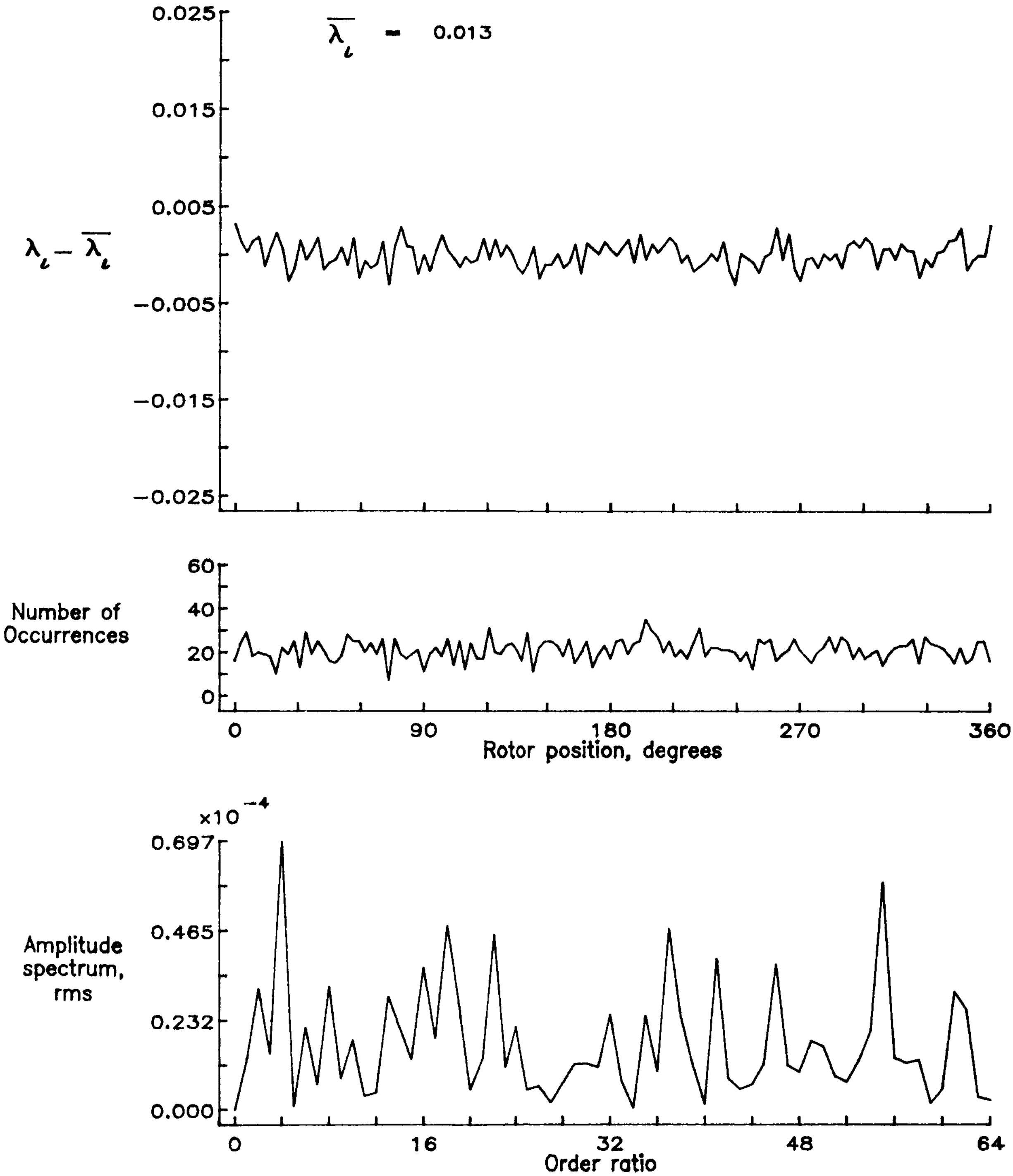


Figure 70.– Concluded.

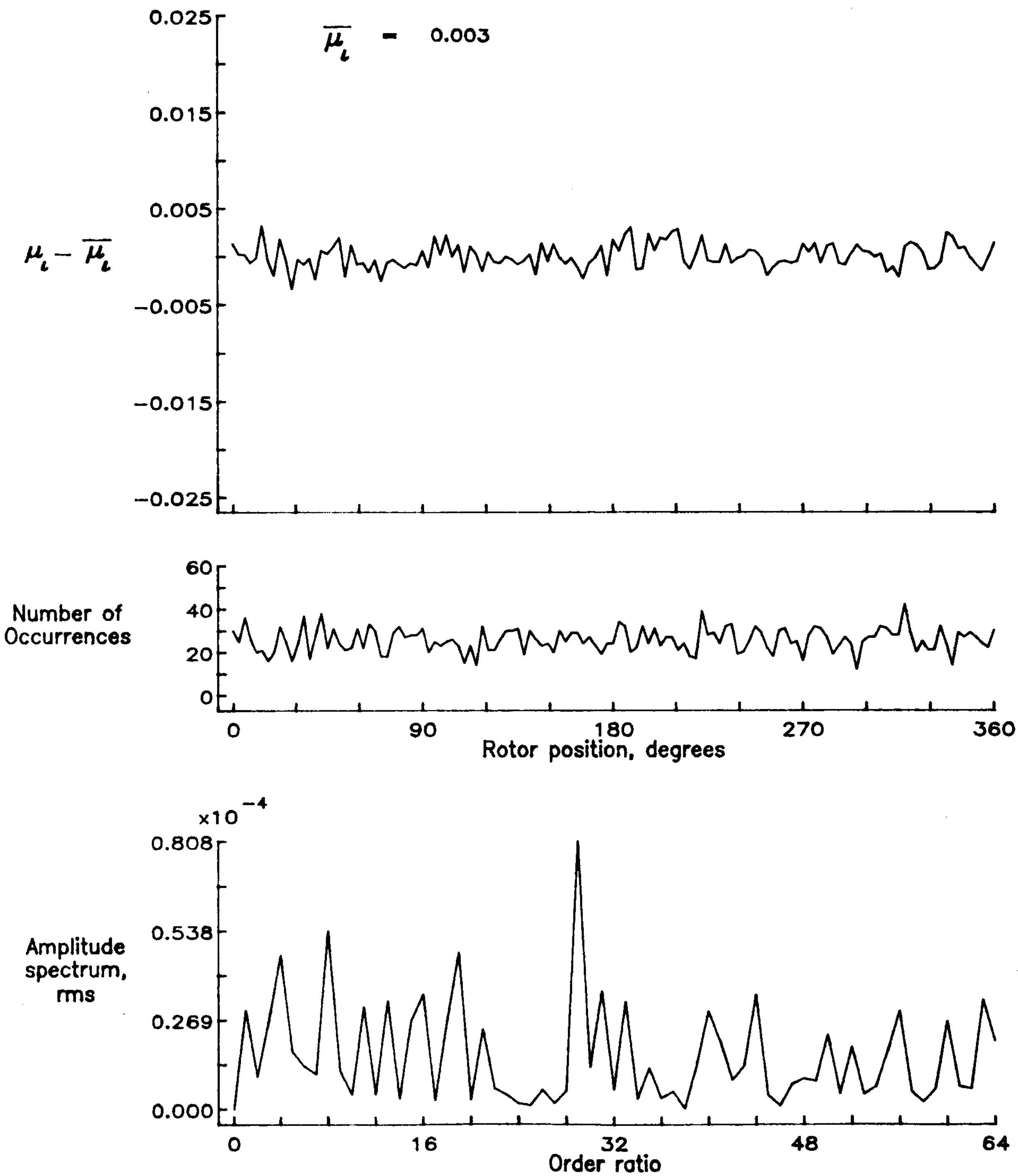


Figure 71.– Induced inflow velocity measured at 90 degrees and r/R of 1.04.

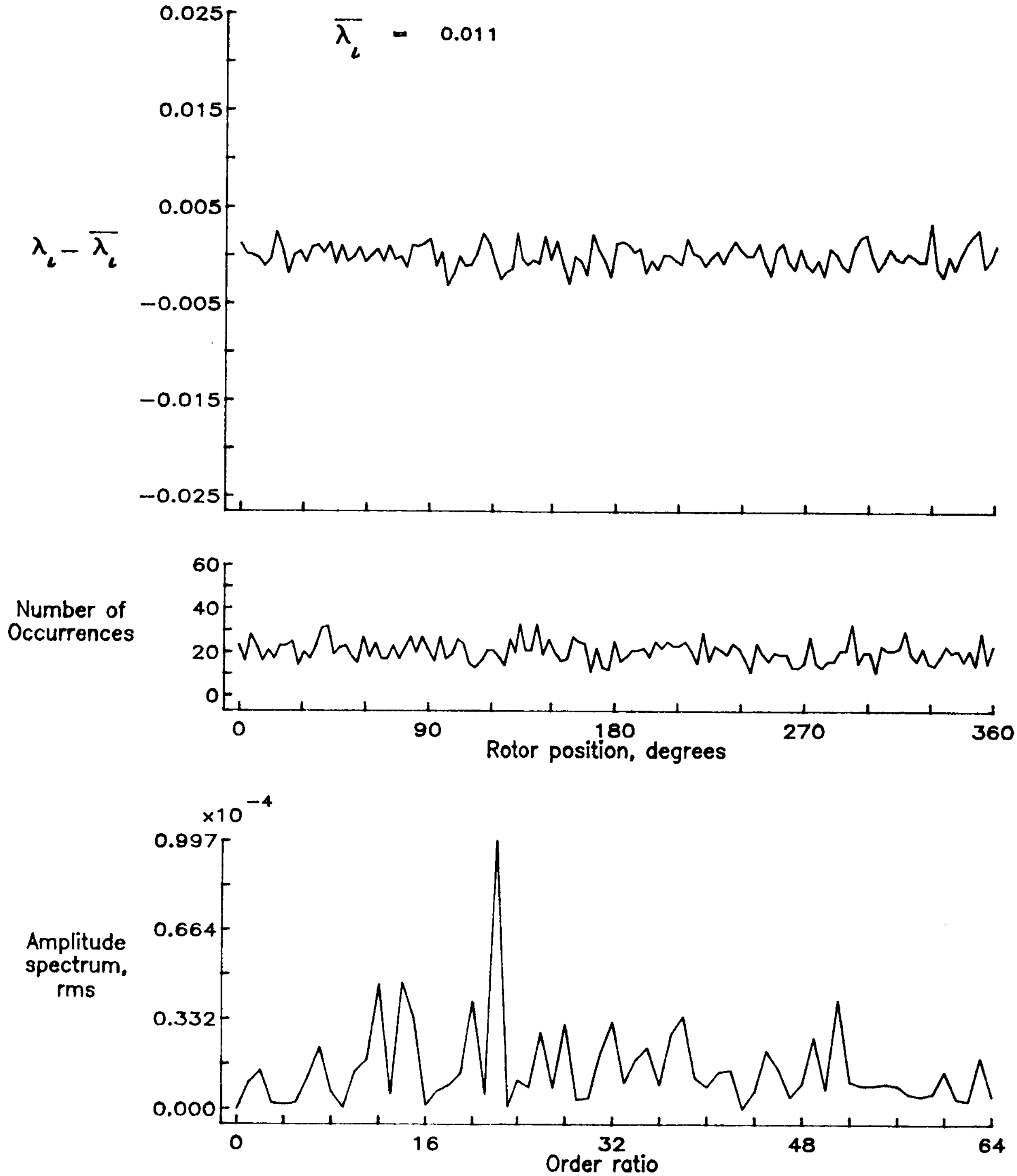


Figure 71.– Concluded.

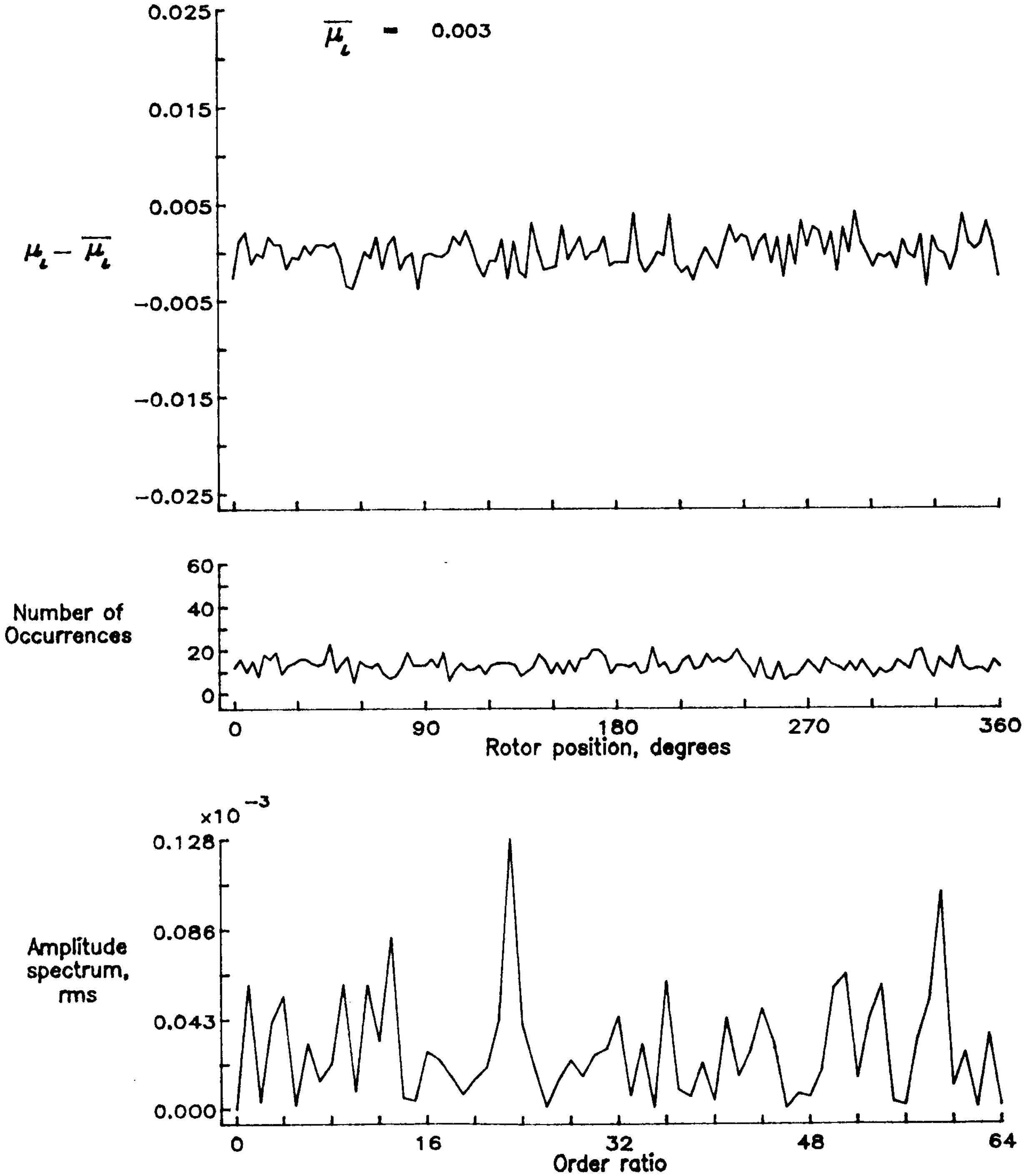
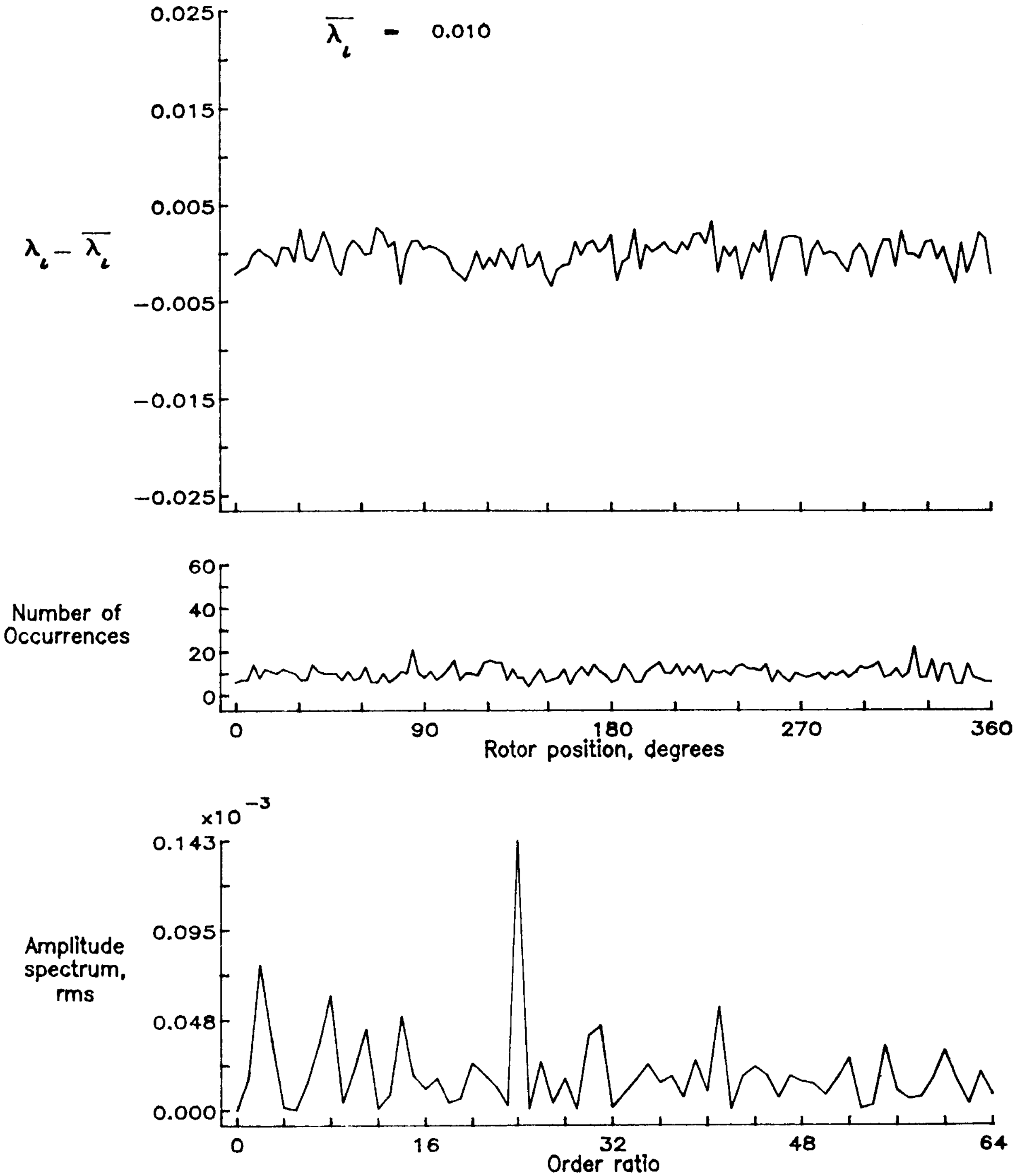


Figure 72.– Induced inflow velocity measured at 90 degrees and r/R of 1.10.



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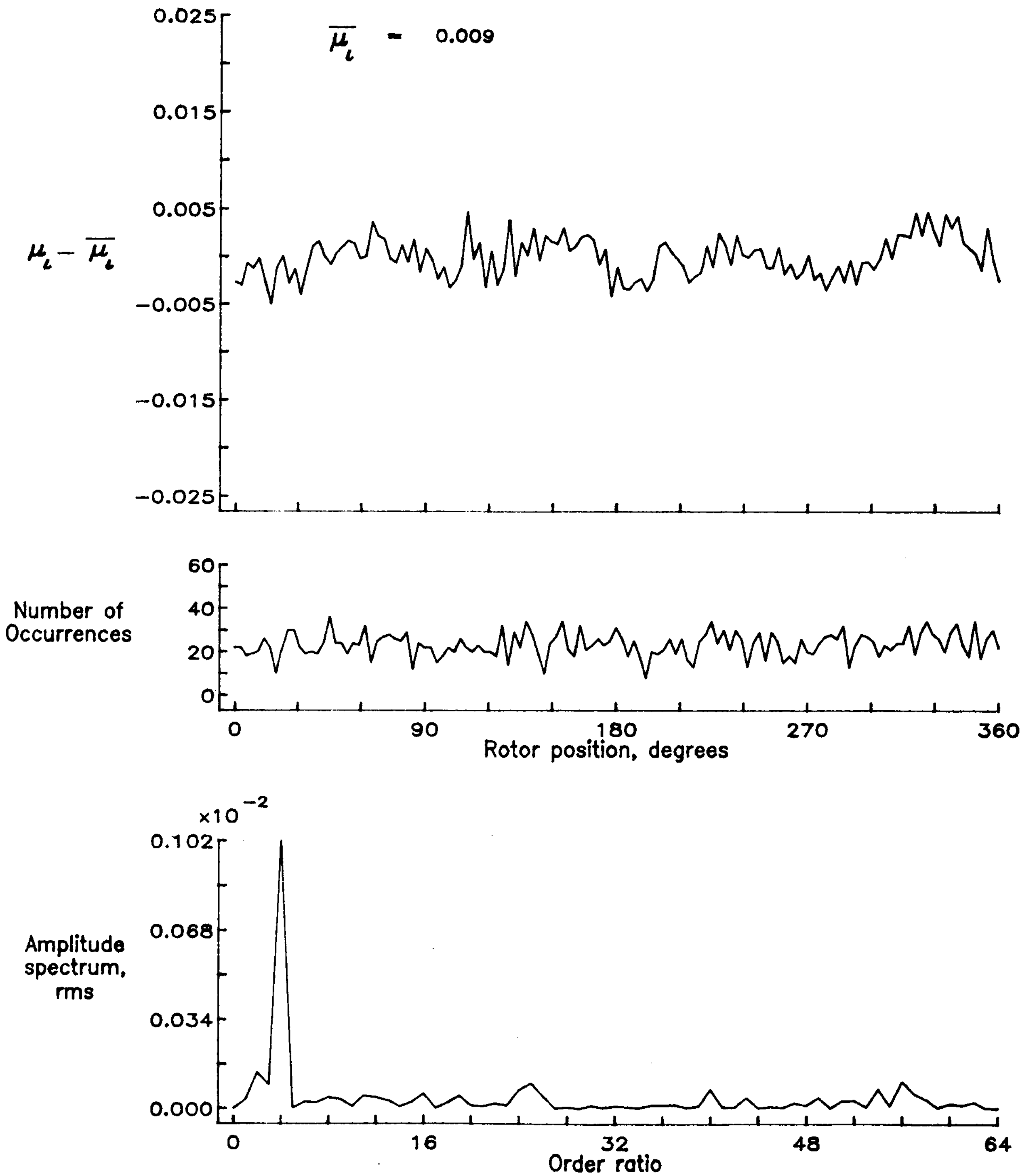
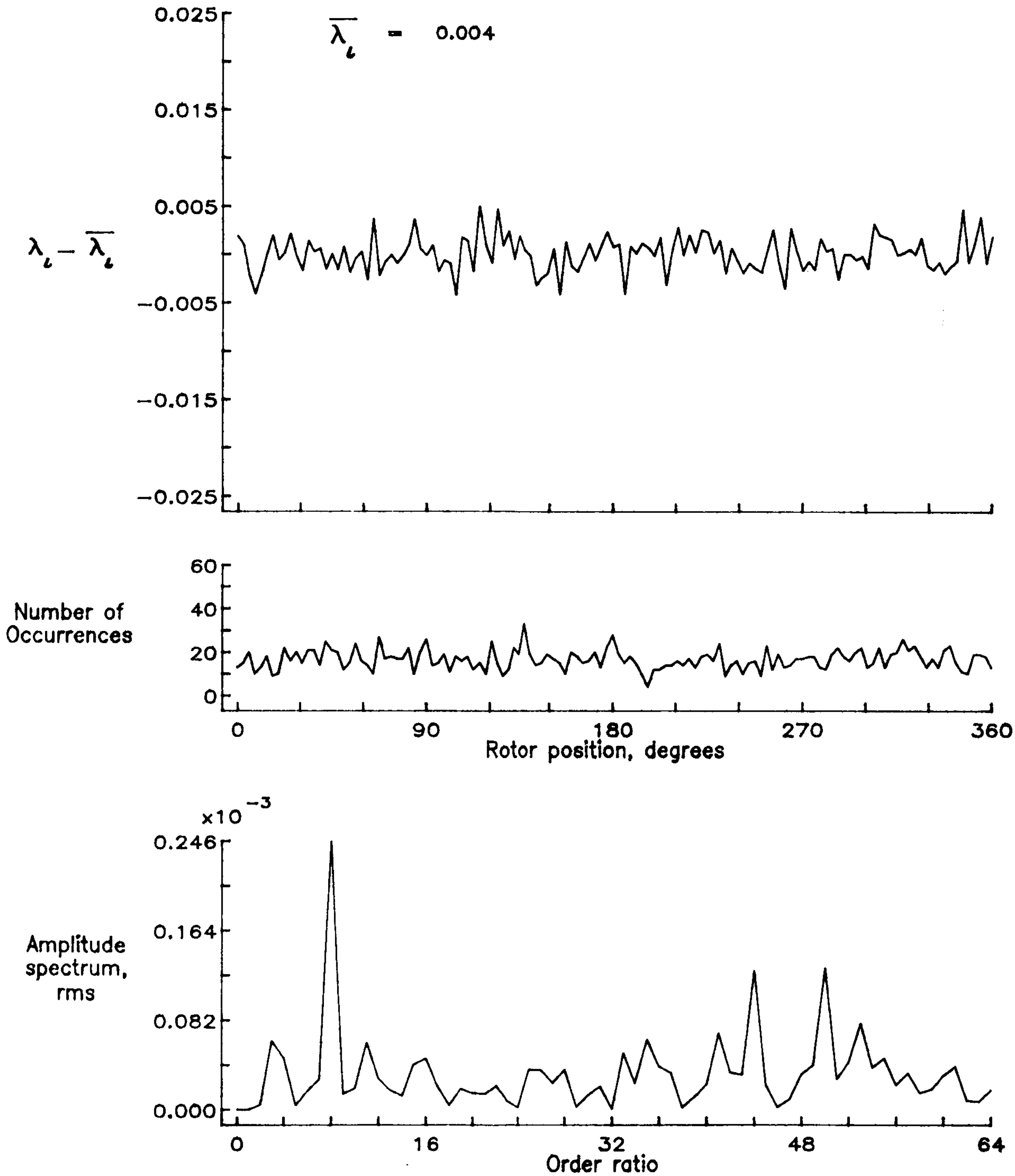


Figure 73.– Induced inflow velocity measured at 120 degrees and r/R of 0.20.



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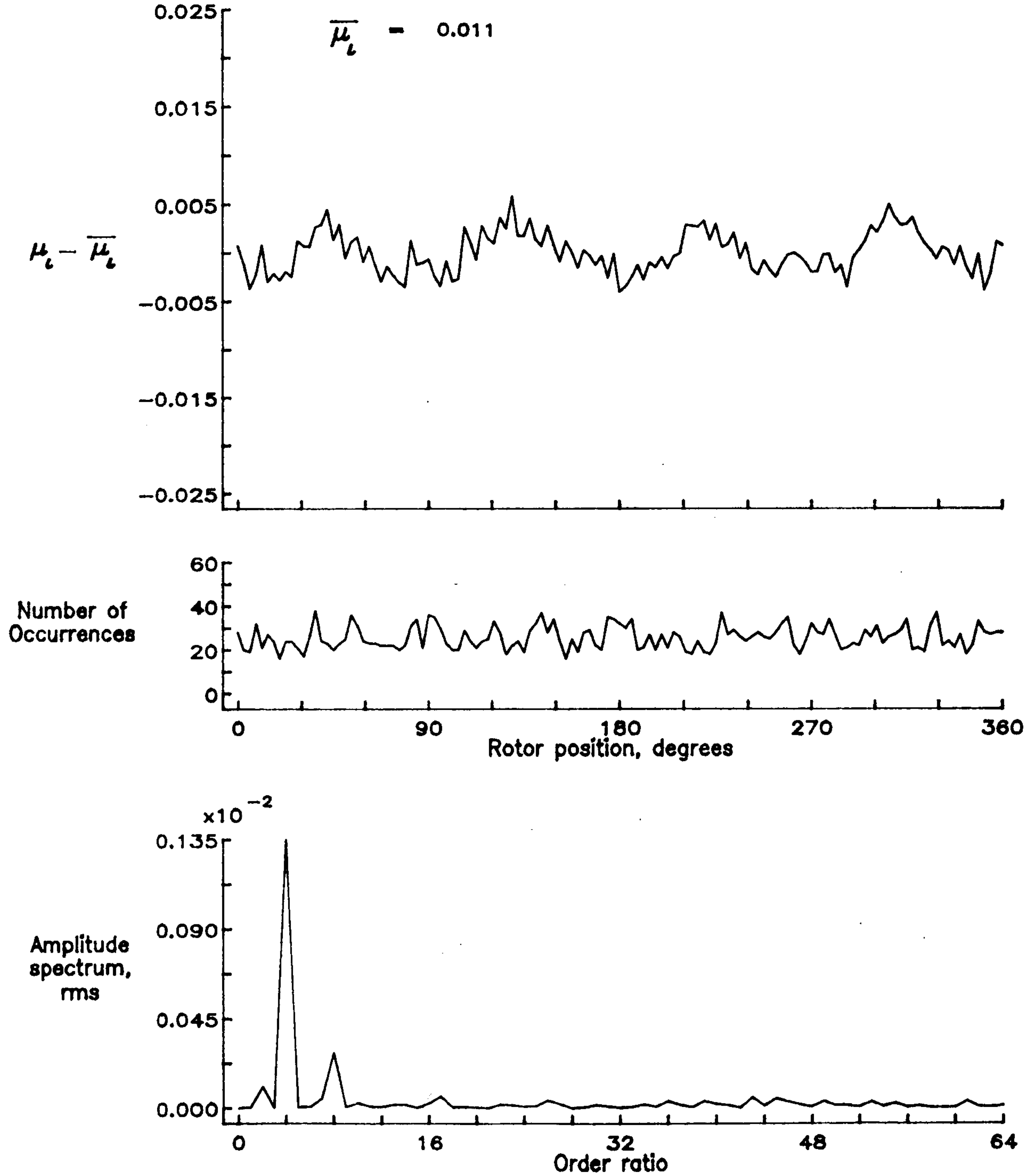


Figure 74.– Induced inflow velocity measured at 120 degrees and r/R of 0.40.

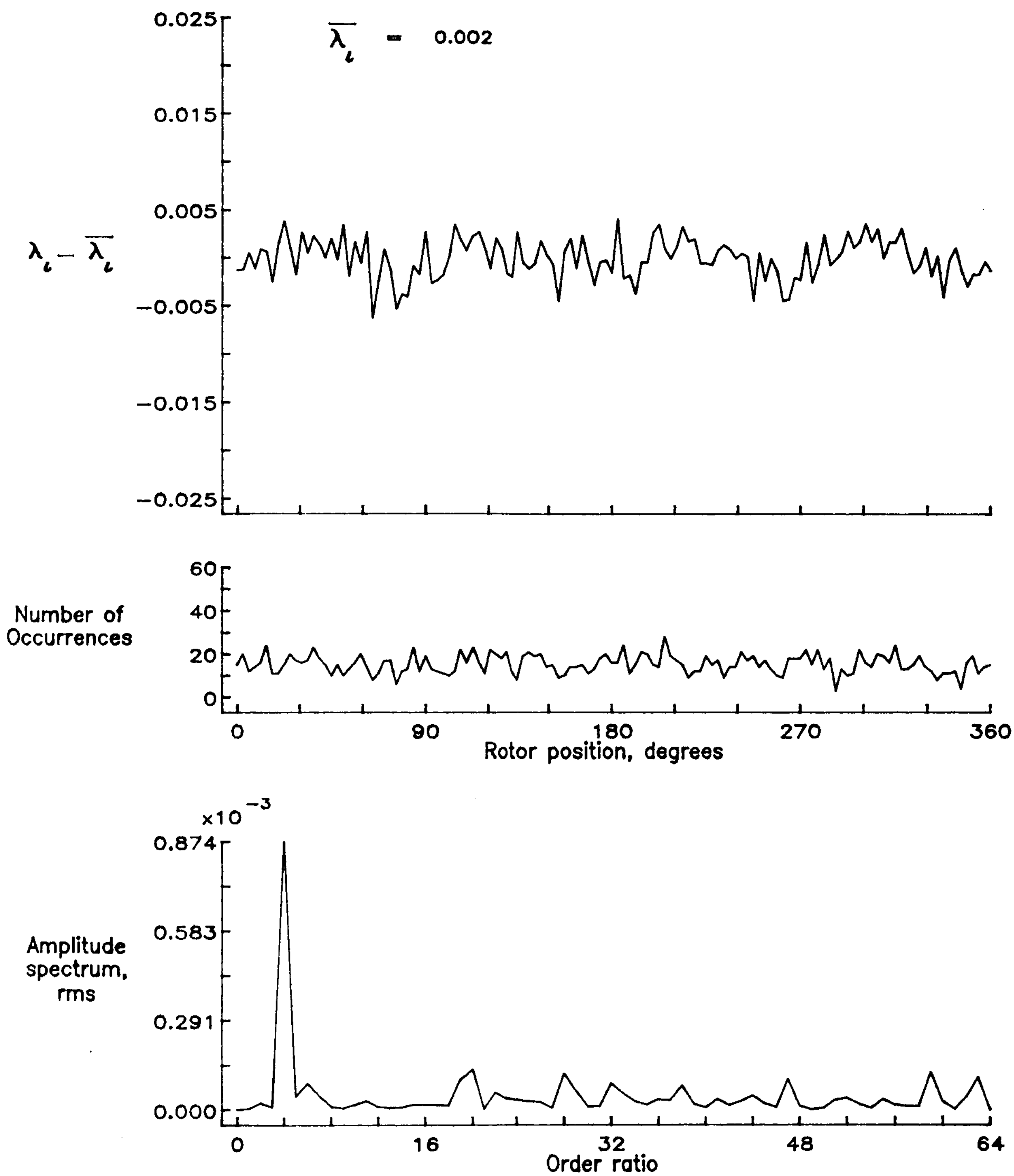


Figure 74.– Concluded.

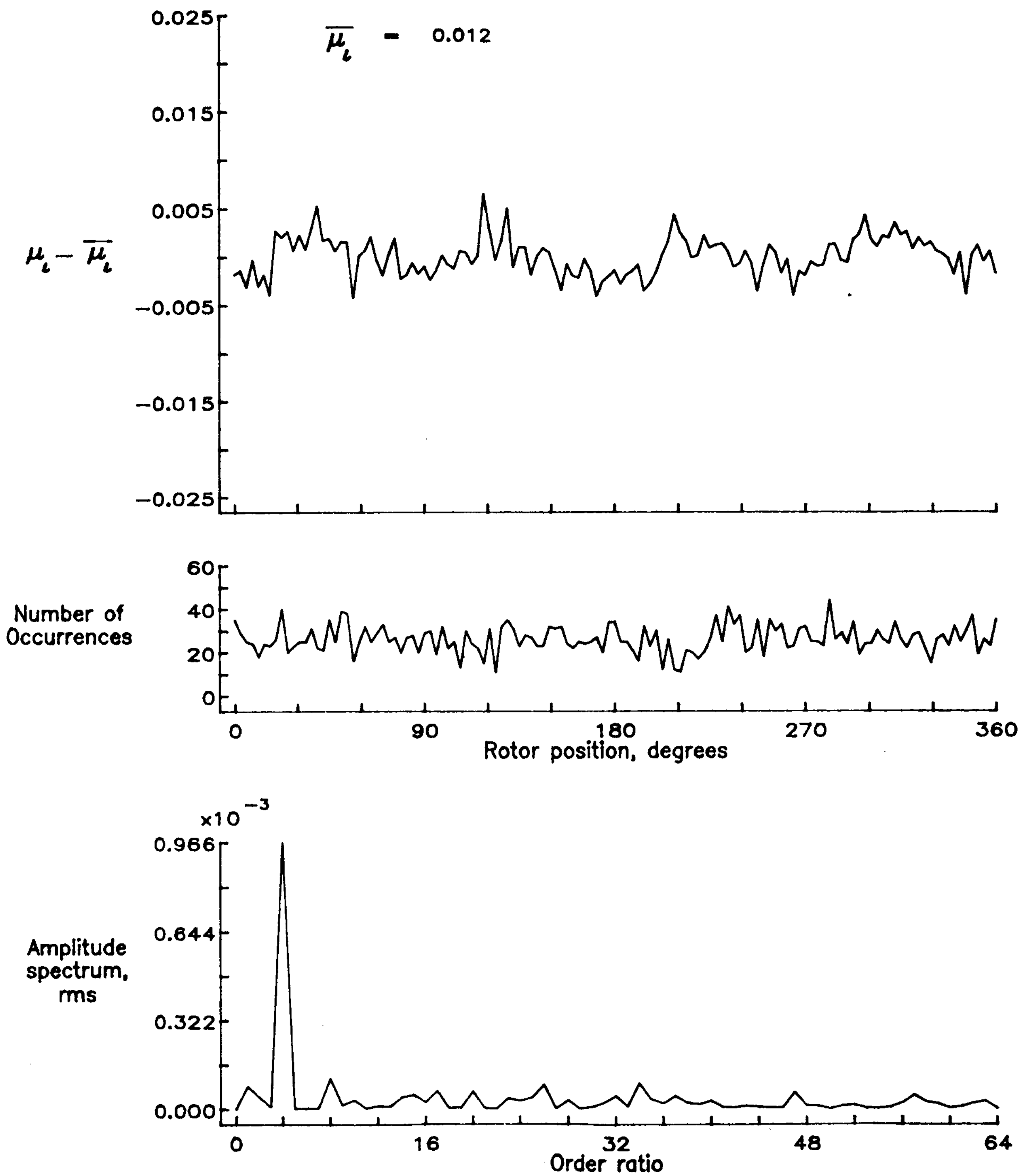


Figure 75.– Induced inflow velocity measured at 120 degrees and r/R of 0.50.

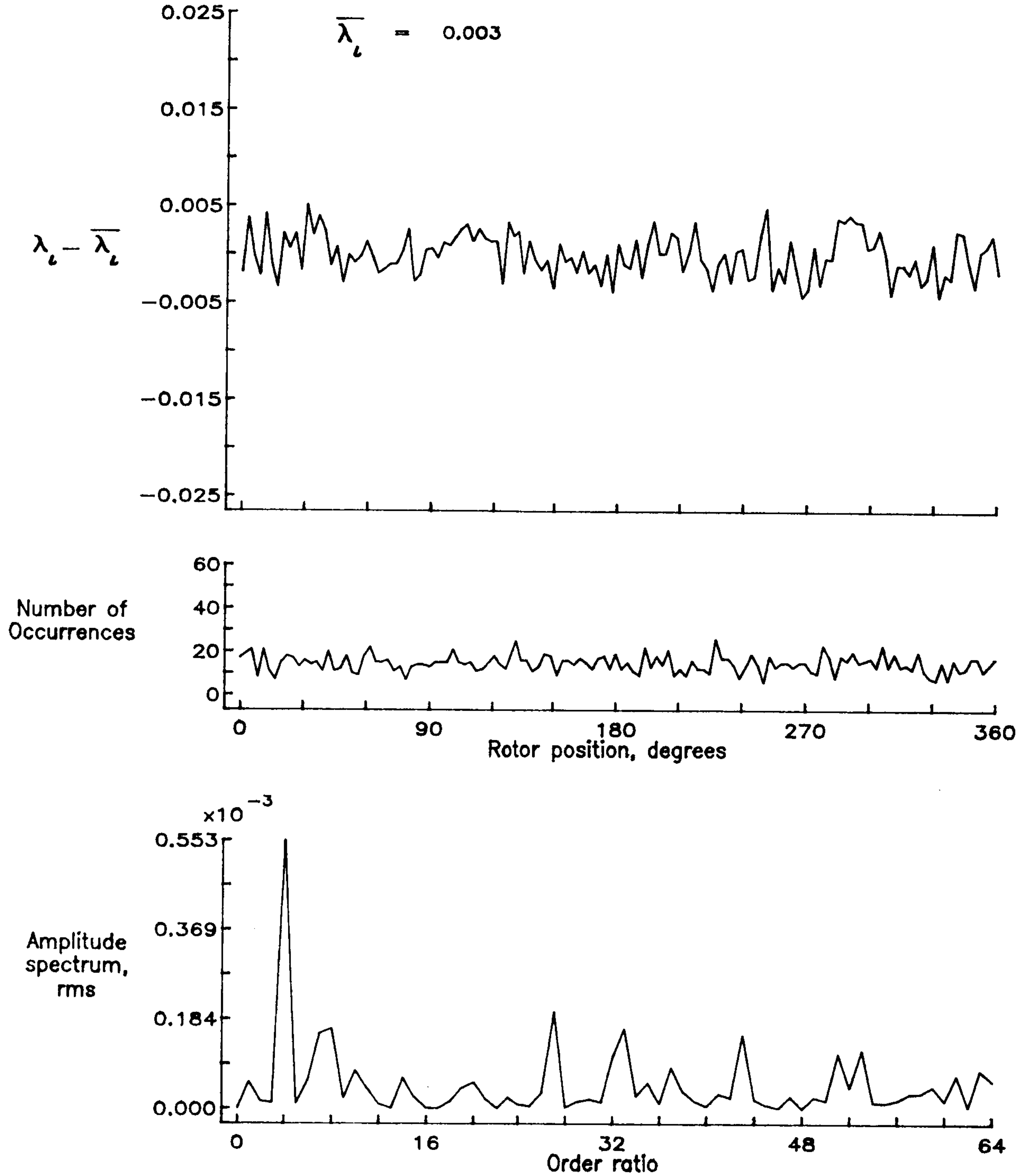


Figure 75.– Concluded.

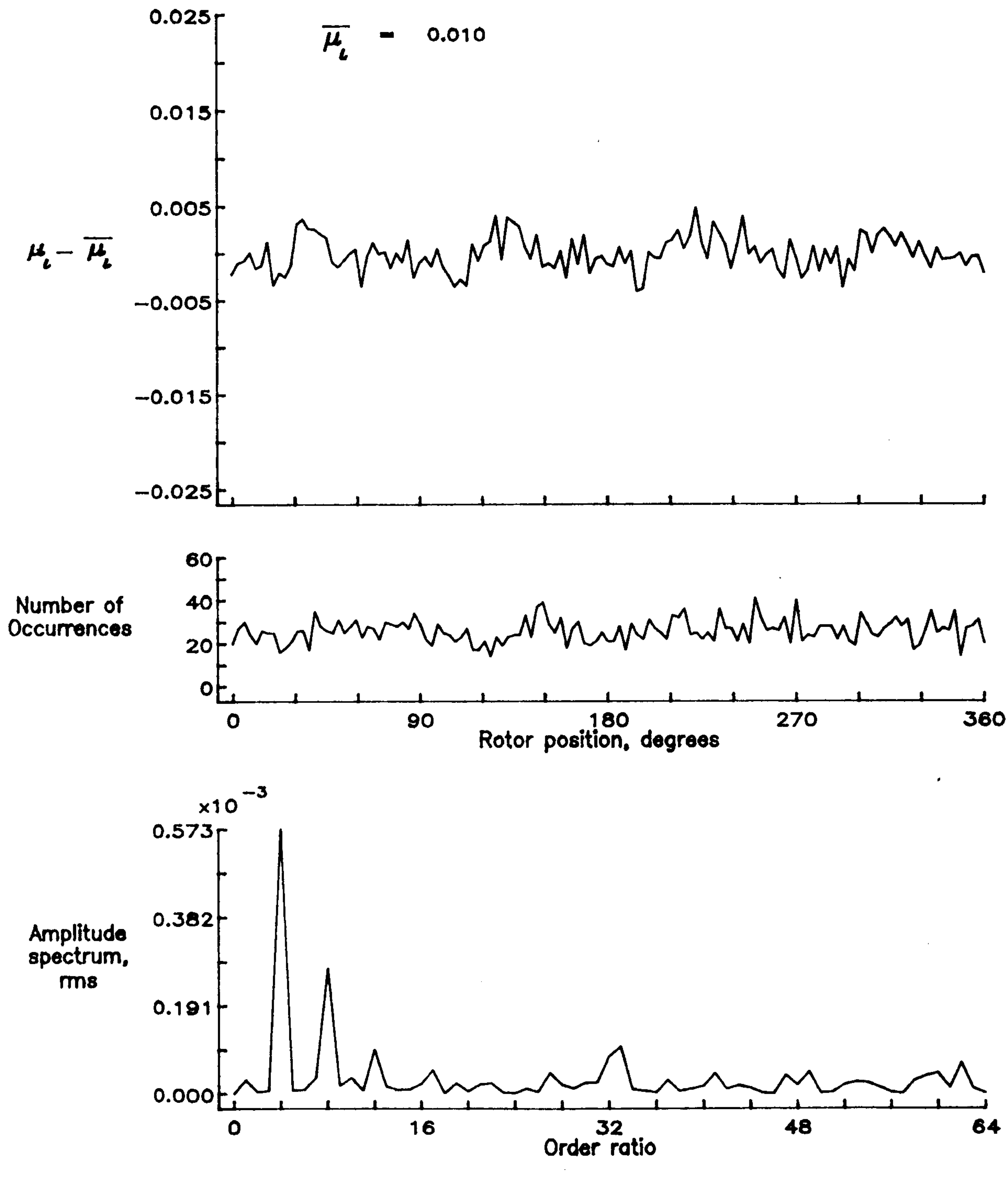


Figure 76.– Induced inflow velocity measured at 120 degrees and r/R of 0.60.

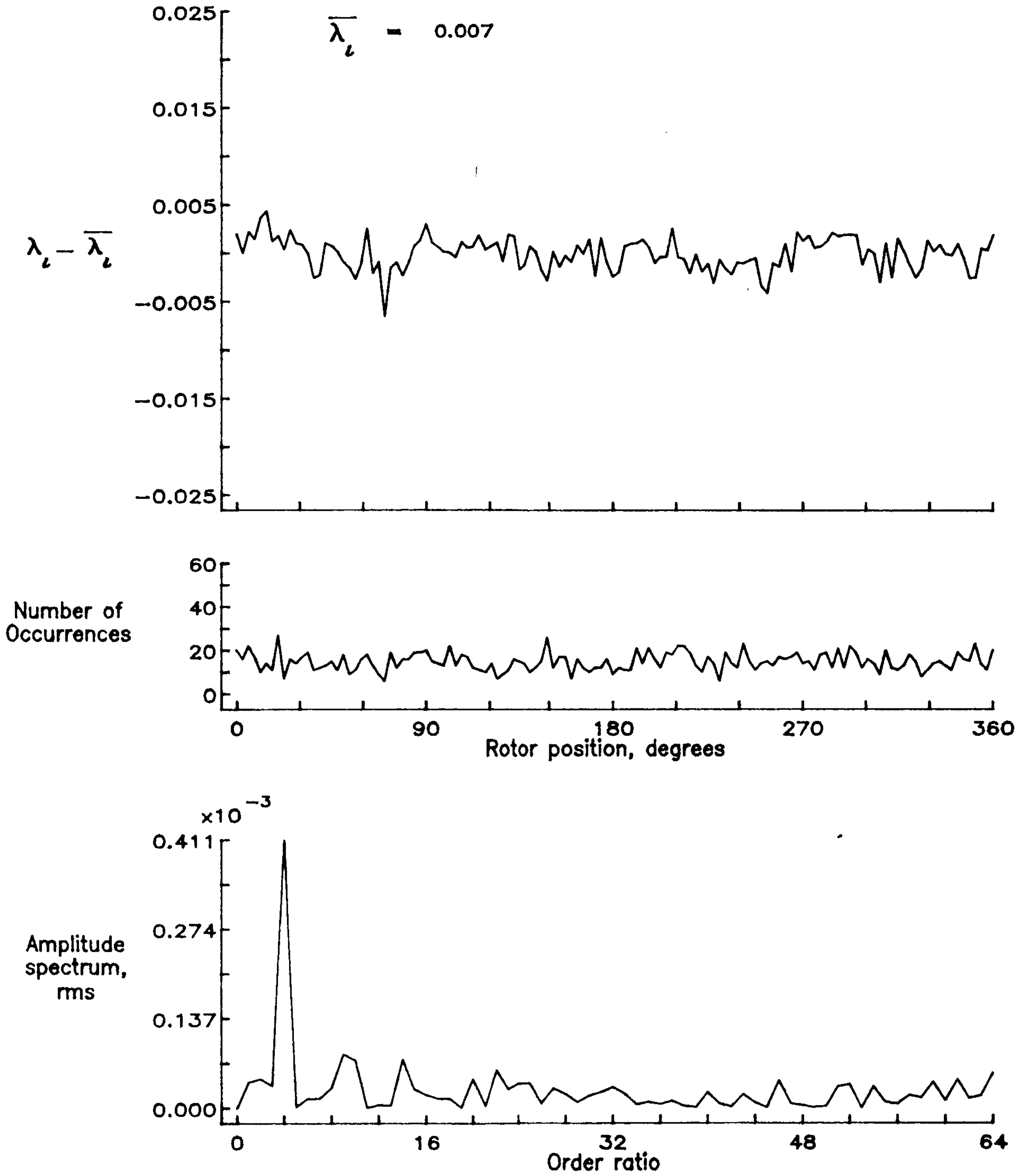


Figure 76.– Concluded.

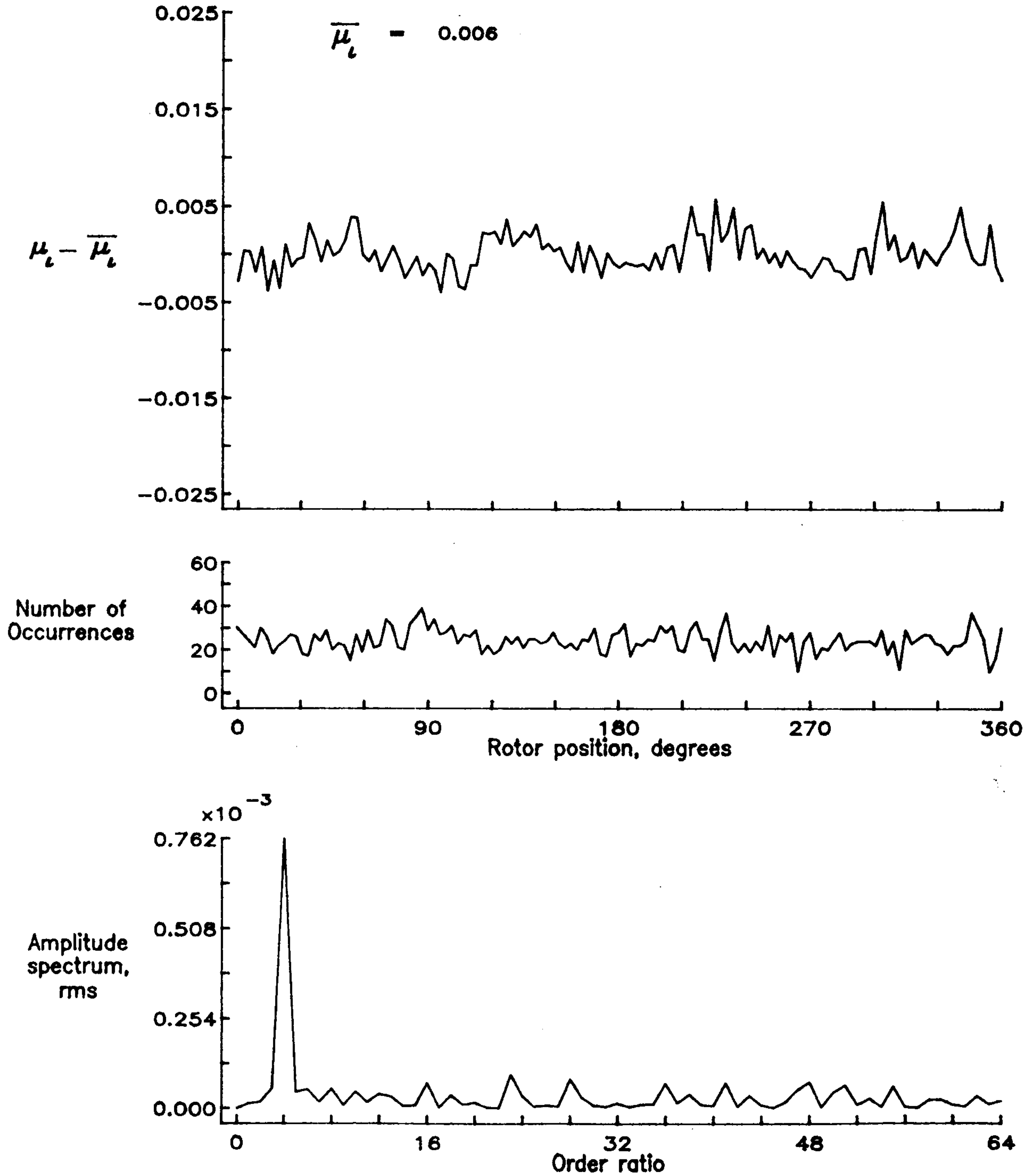


Figure 77.– Induced inflow velocity measured at 120 degrees and r/R of 0.70.

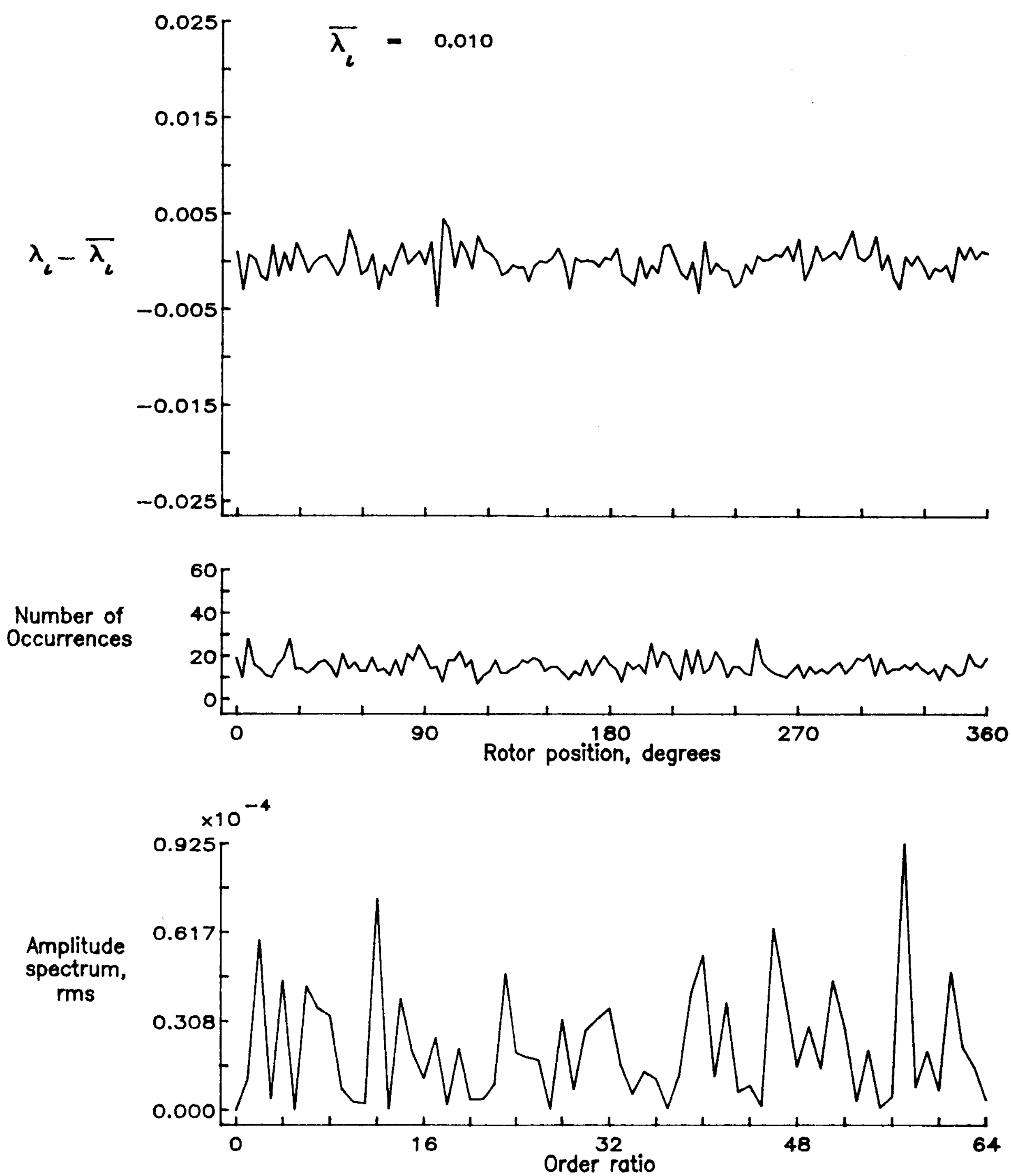


Figure 77.– Concluded.

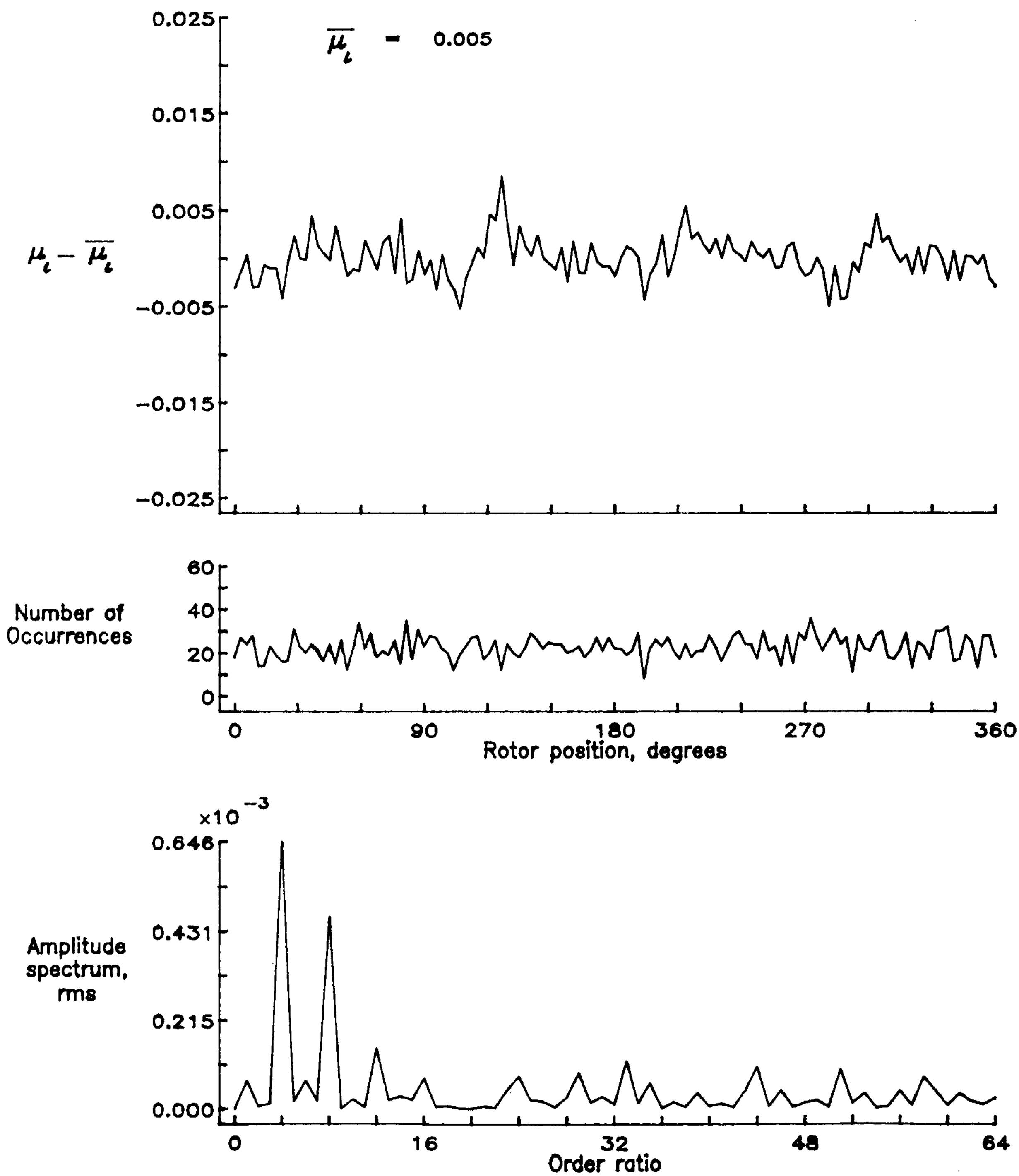
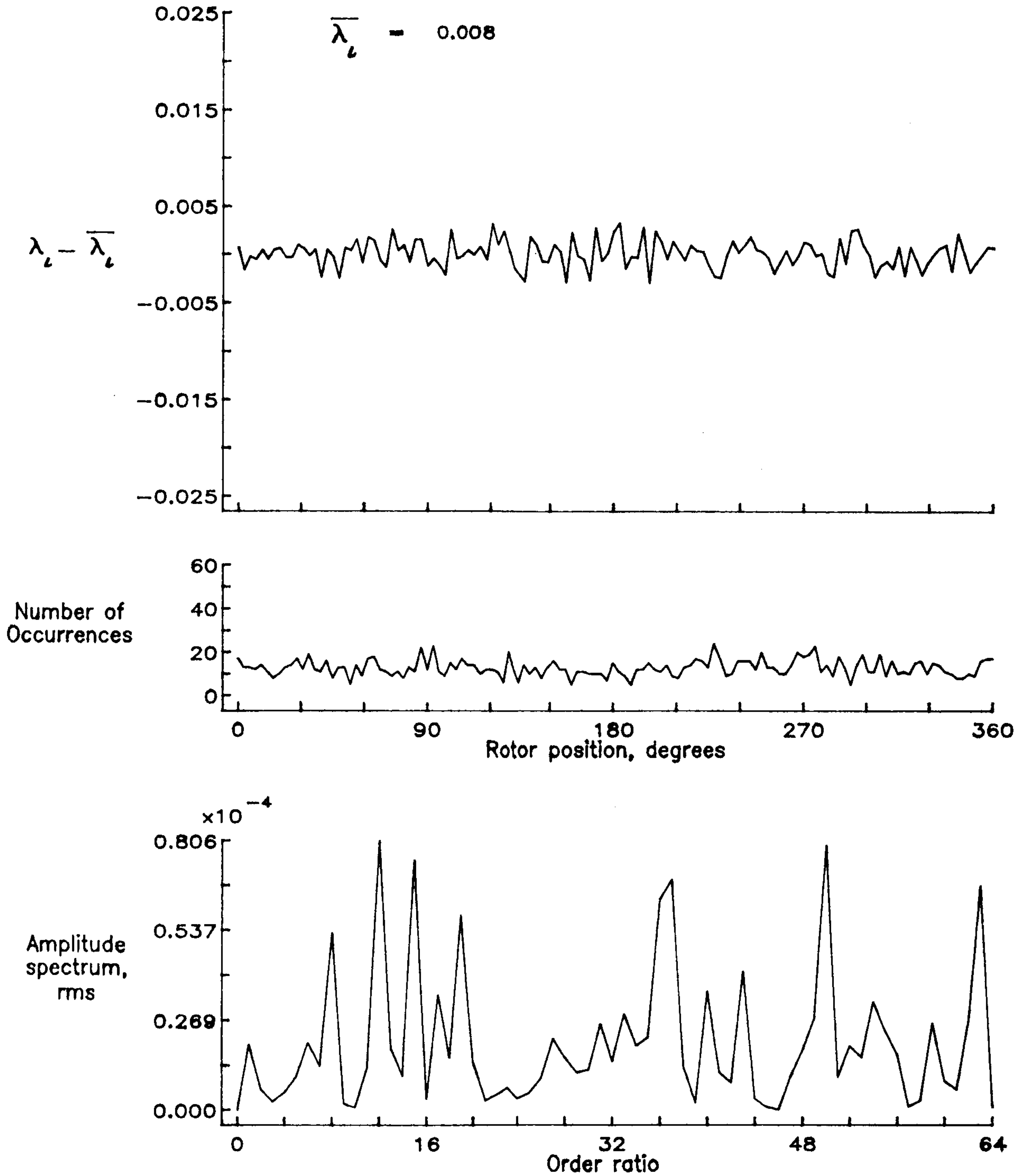


Figure 78.– Induced inflow velocity measured at 120 degrees and r/R of 0.74.



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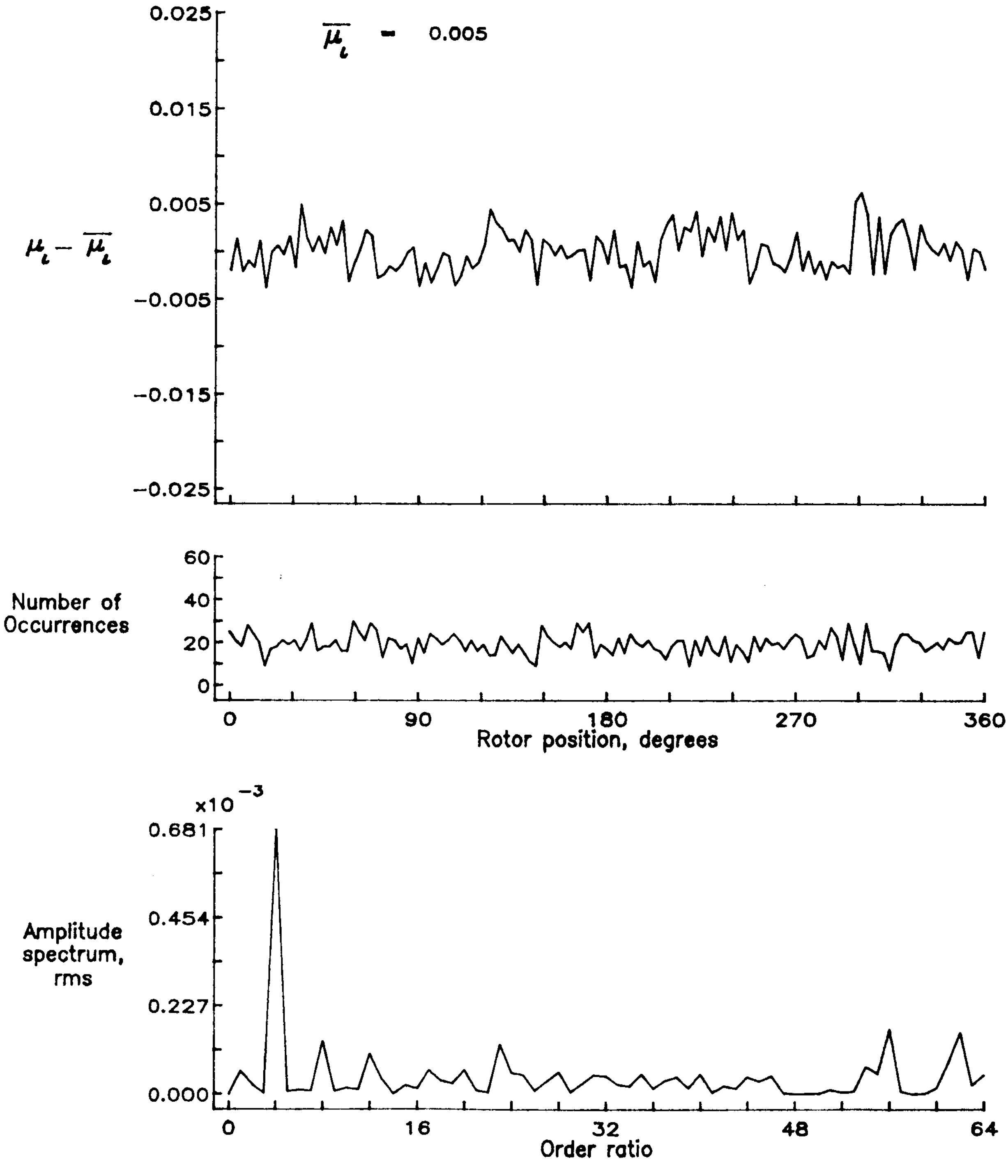


Figure 79.– Induced inflow velocity measured at 120 degrees and r/R of 0.78.

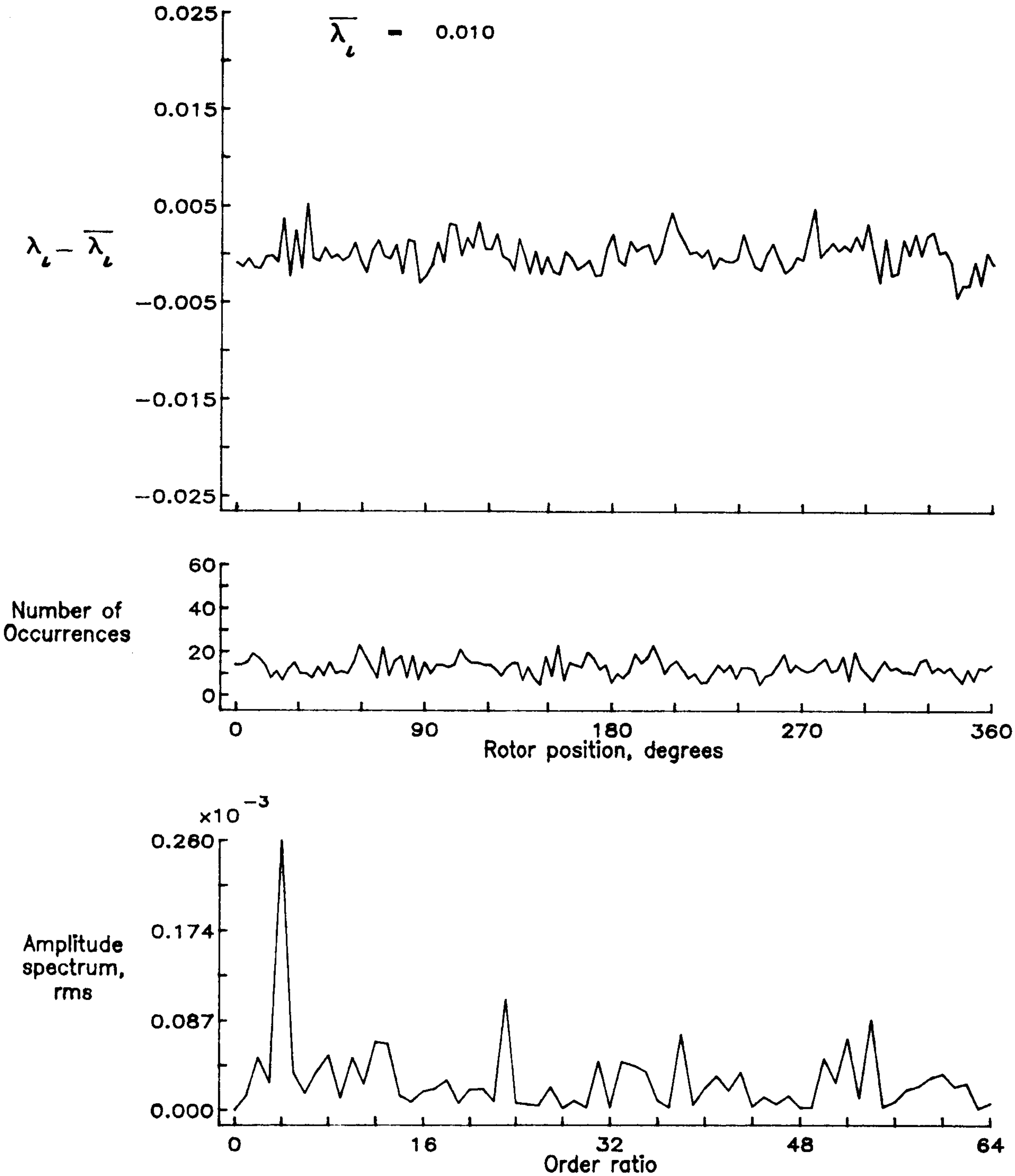


Figure 79.– Concluded.

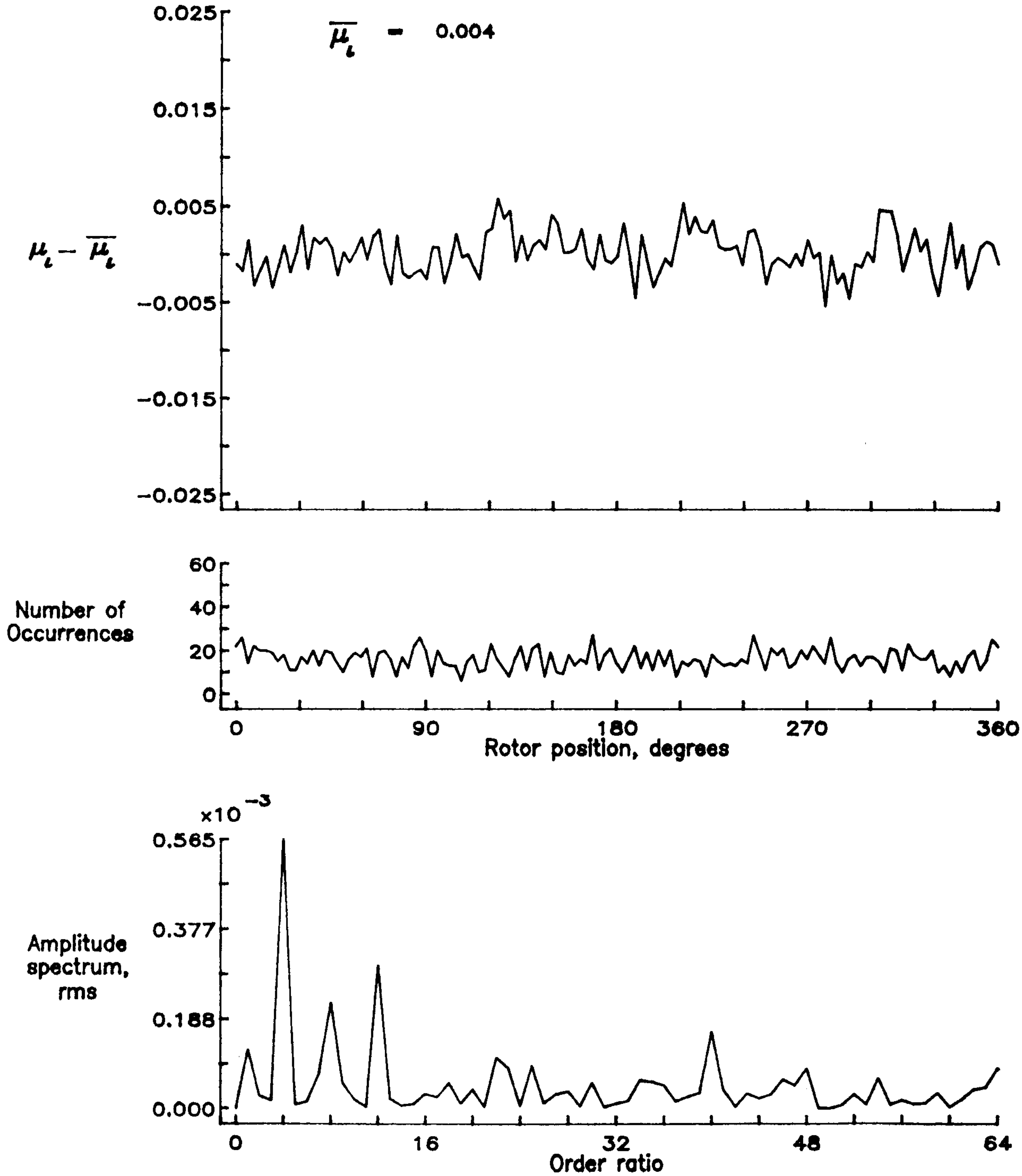


Figure 80.– Induced inflow velocity measured at 120 degrees and r/R of 0.82.

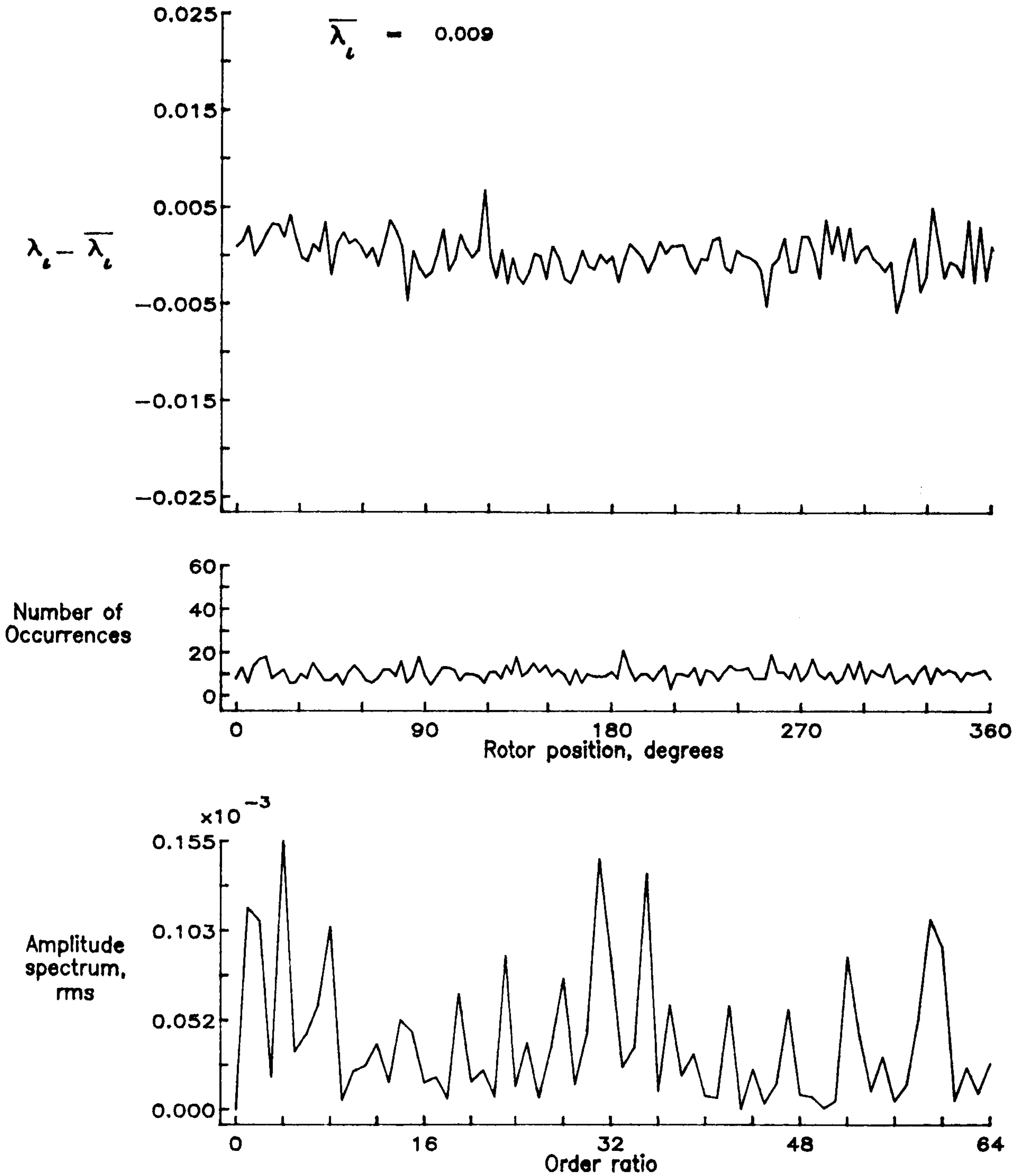


Figure 80.– Concluded.

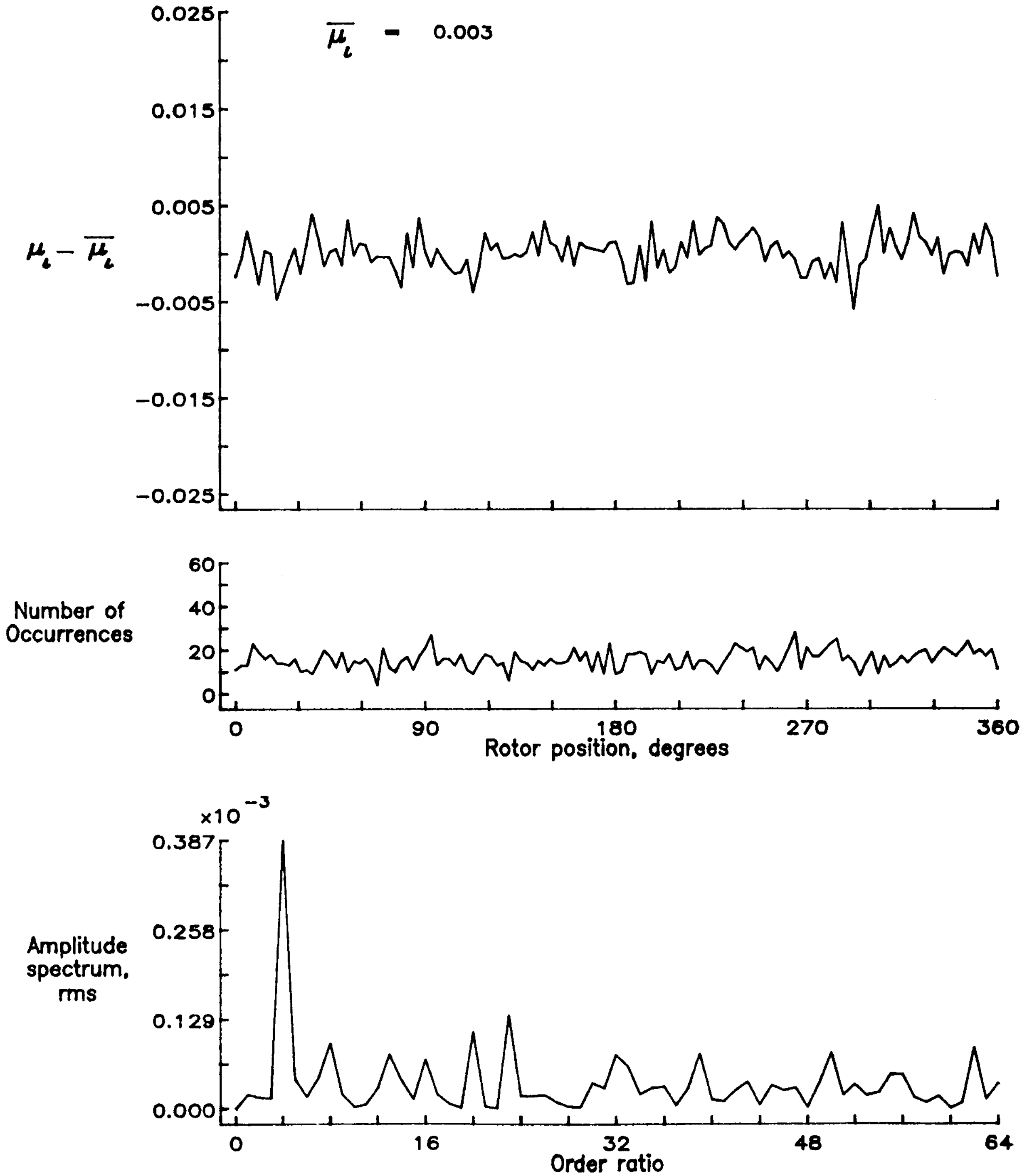


Figure 81.— Induced inflow velocity measured at 120 degrees and r/R of 0.86.

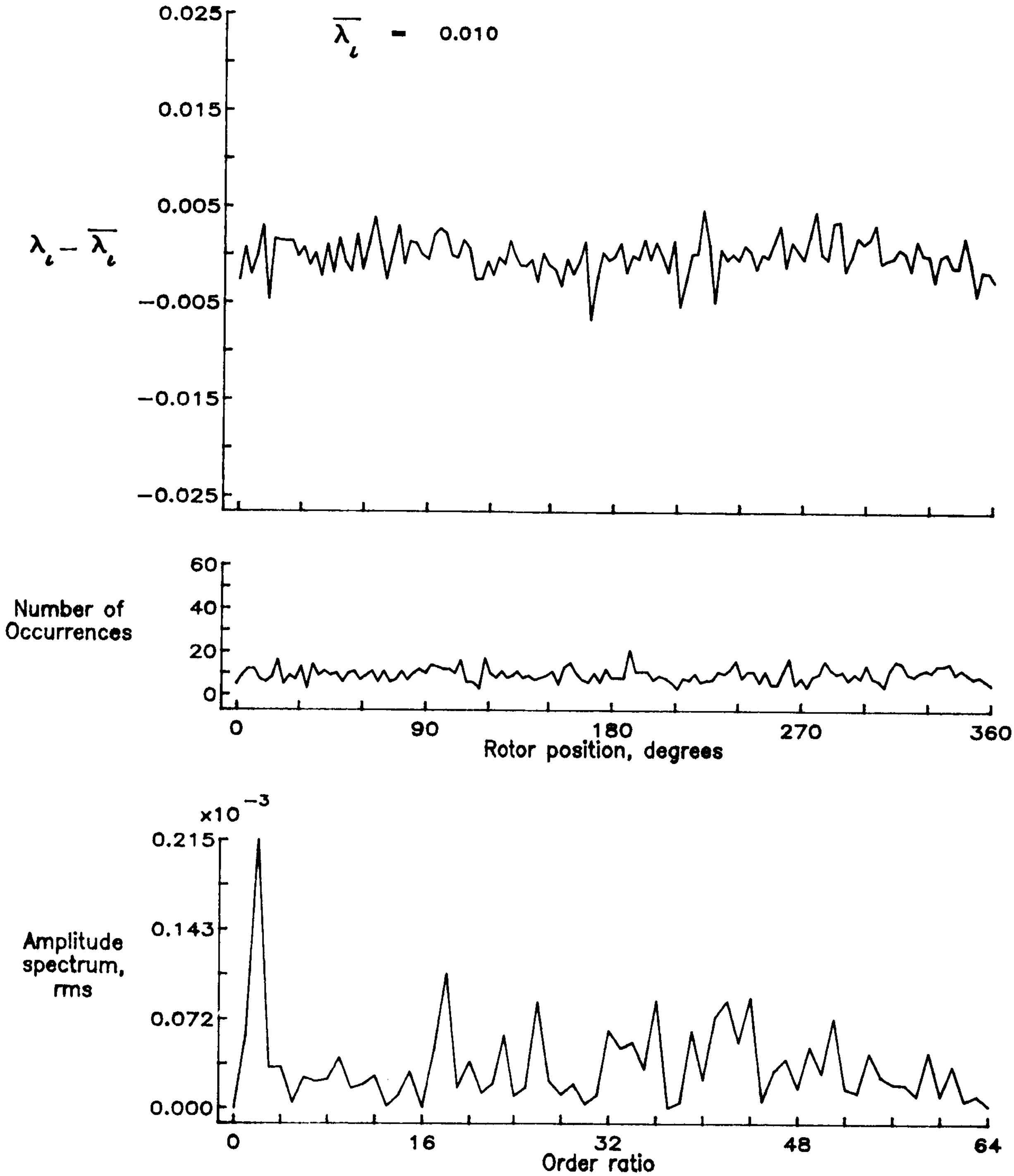


Figure 81.– Concluded.

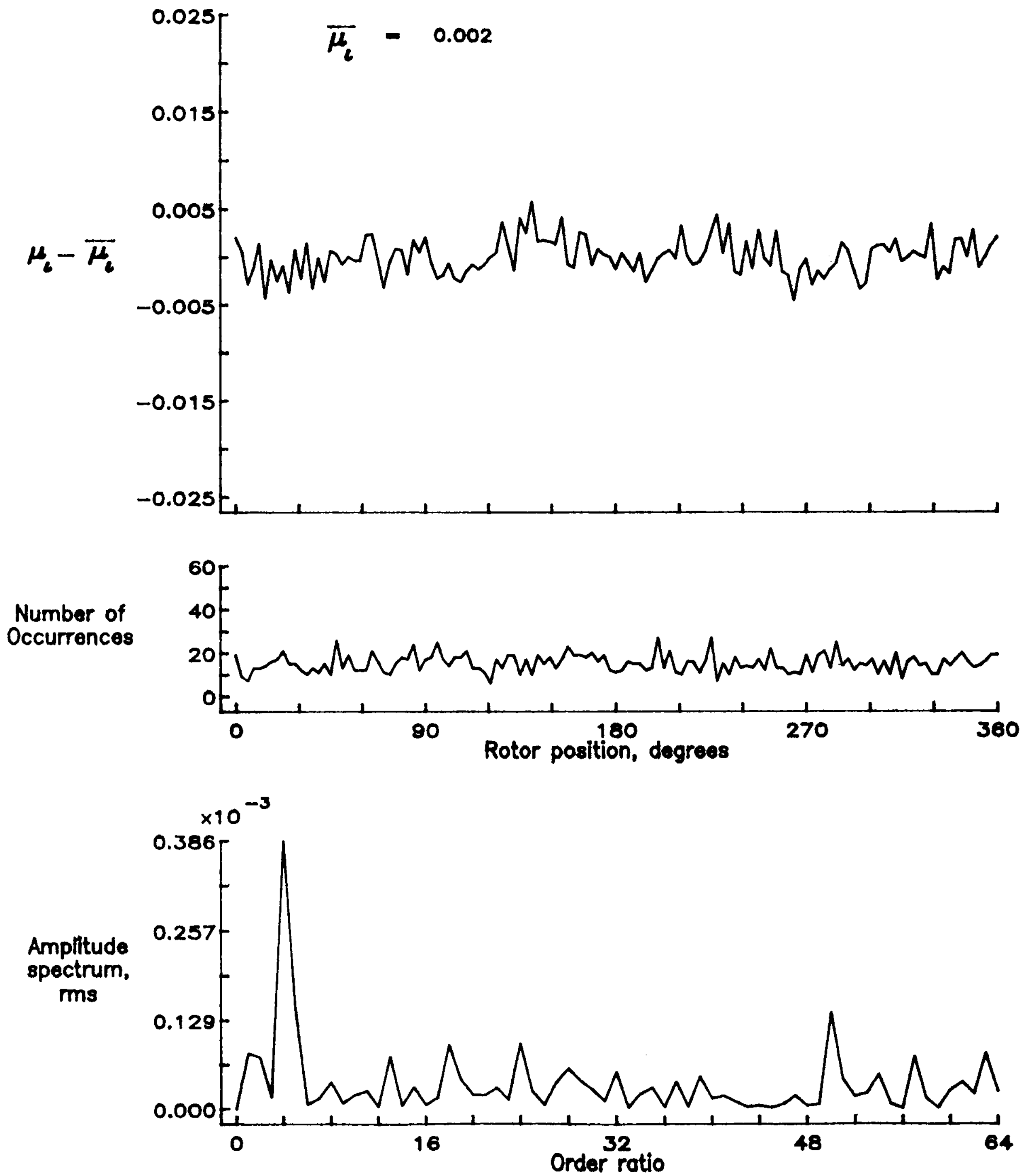


Figure 82.– Induced inflow velocity measured at 120 degrees and r/R of 0.90.

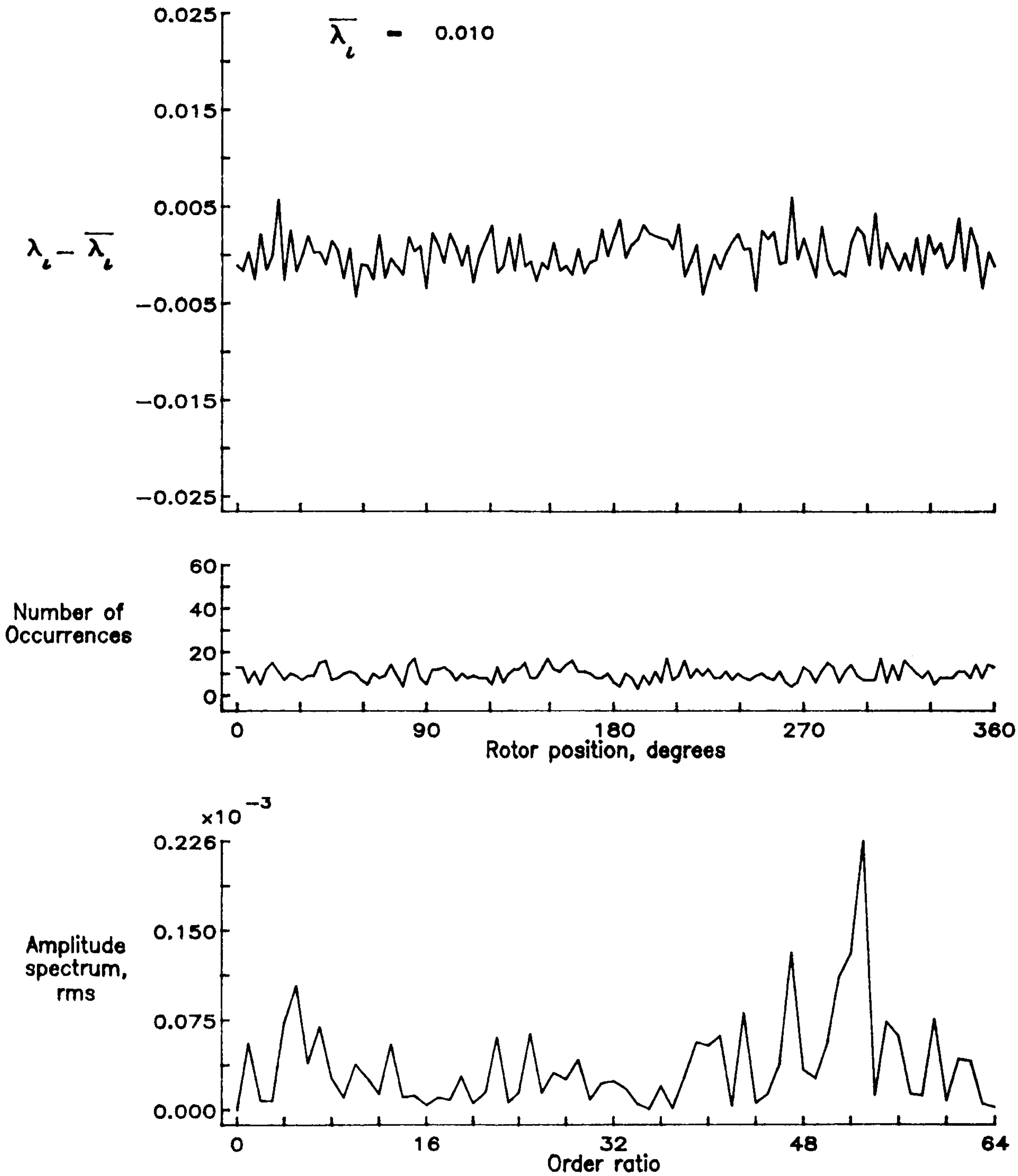


Figure 82.– Concluded.

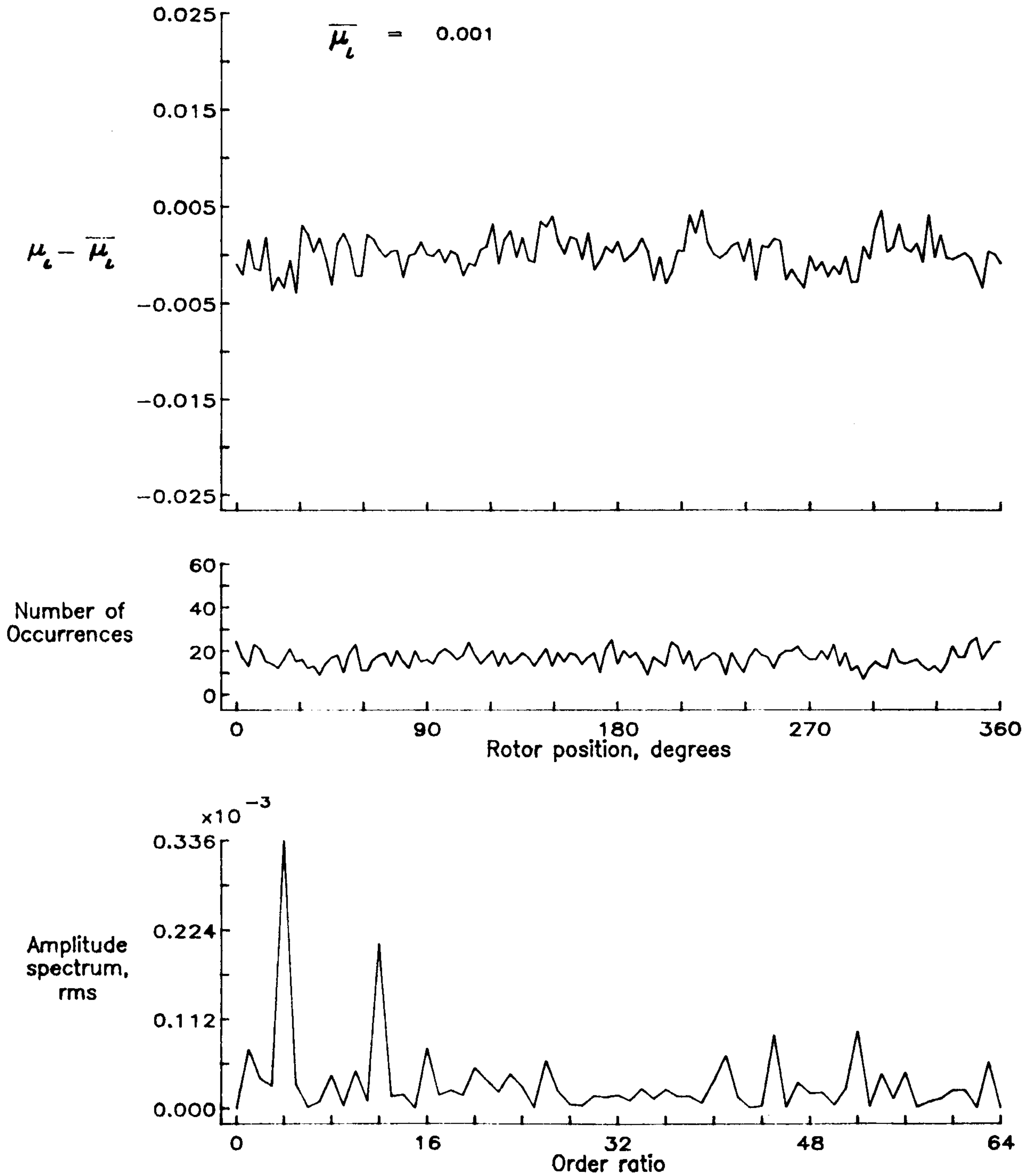
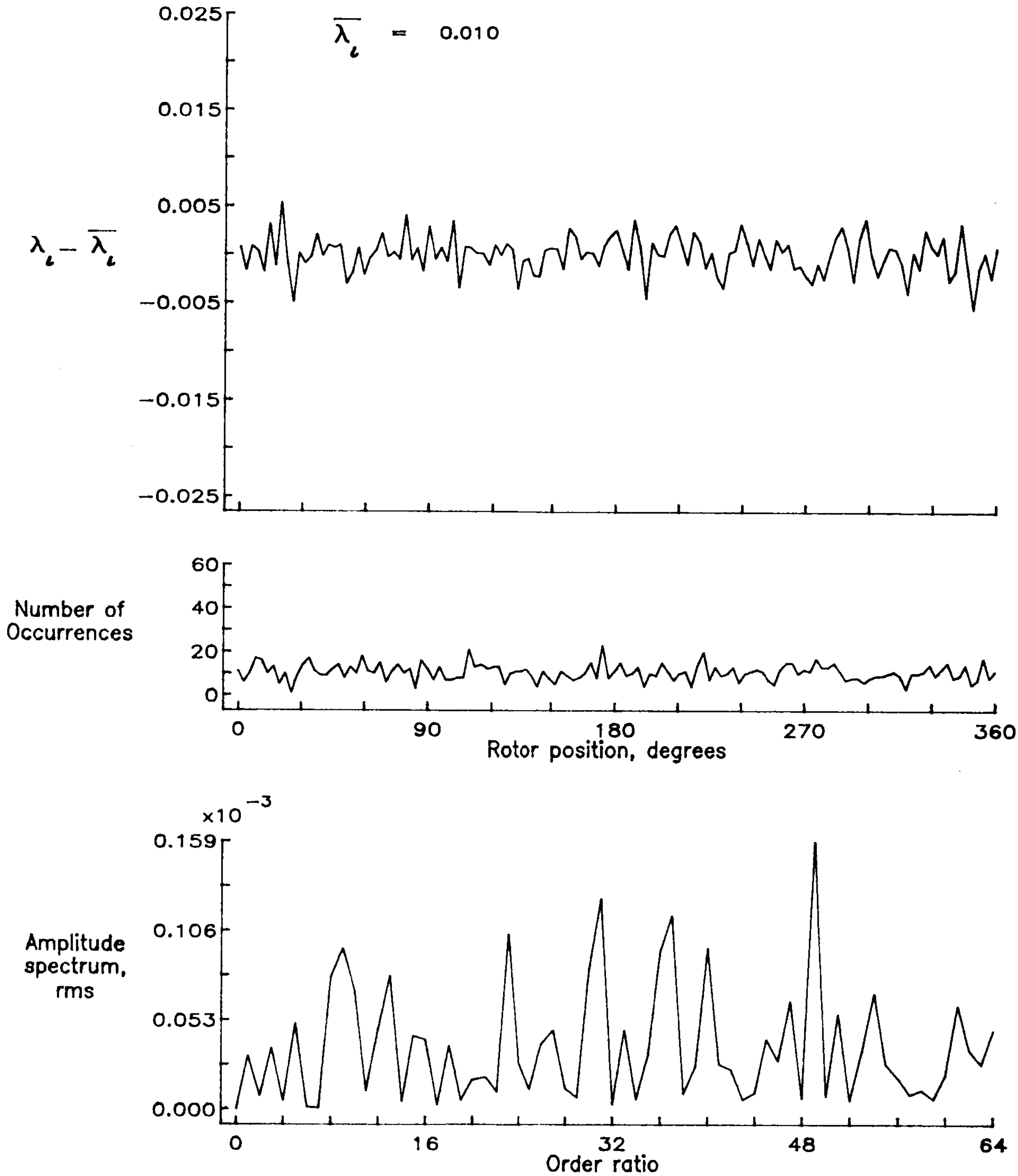


Figure 83.– Induced inflow velocity measured at 120 degrees and r/R of 0.94.



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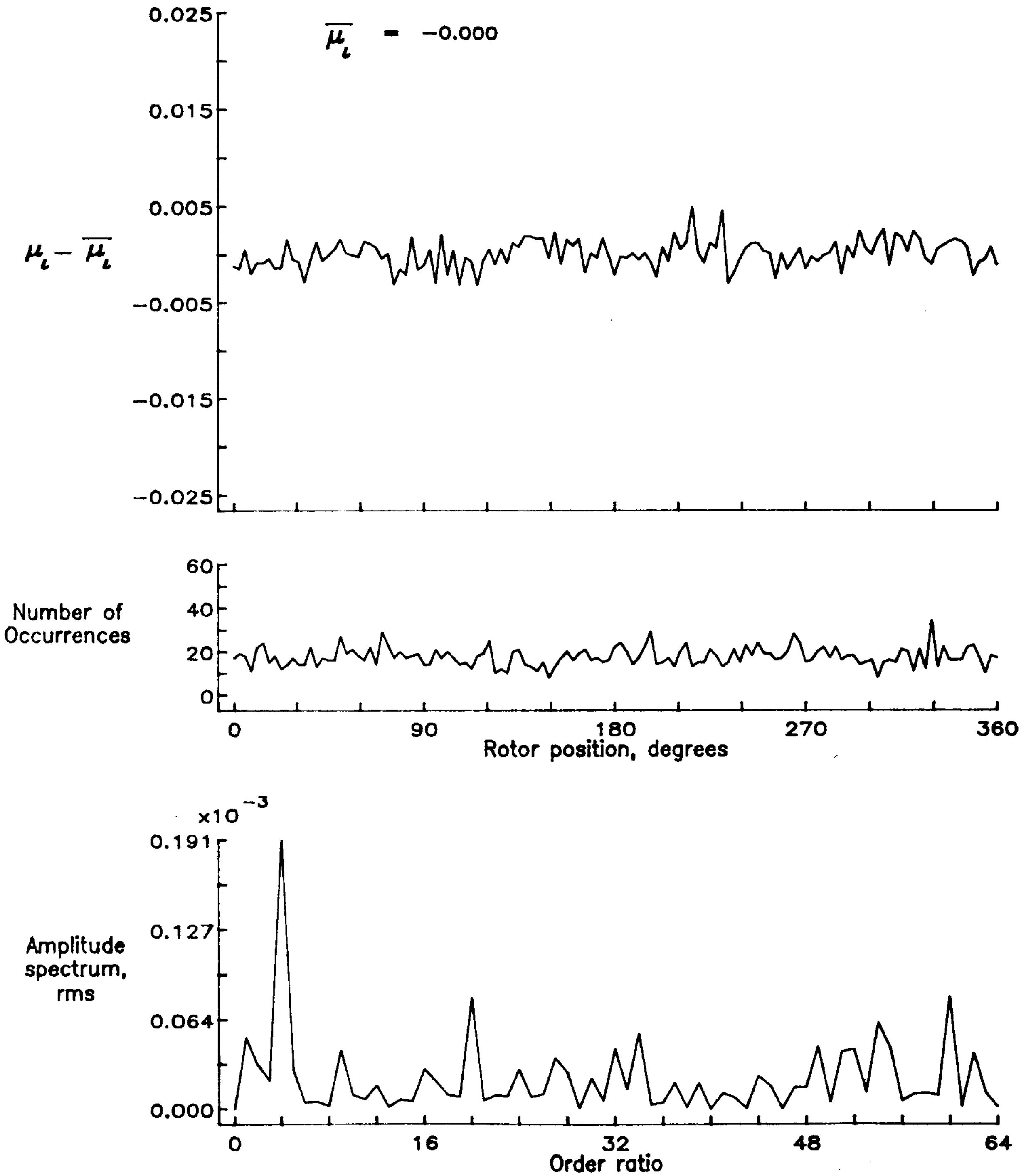
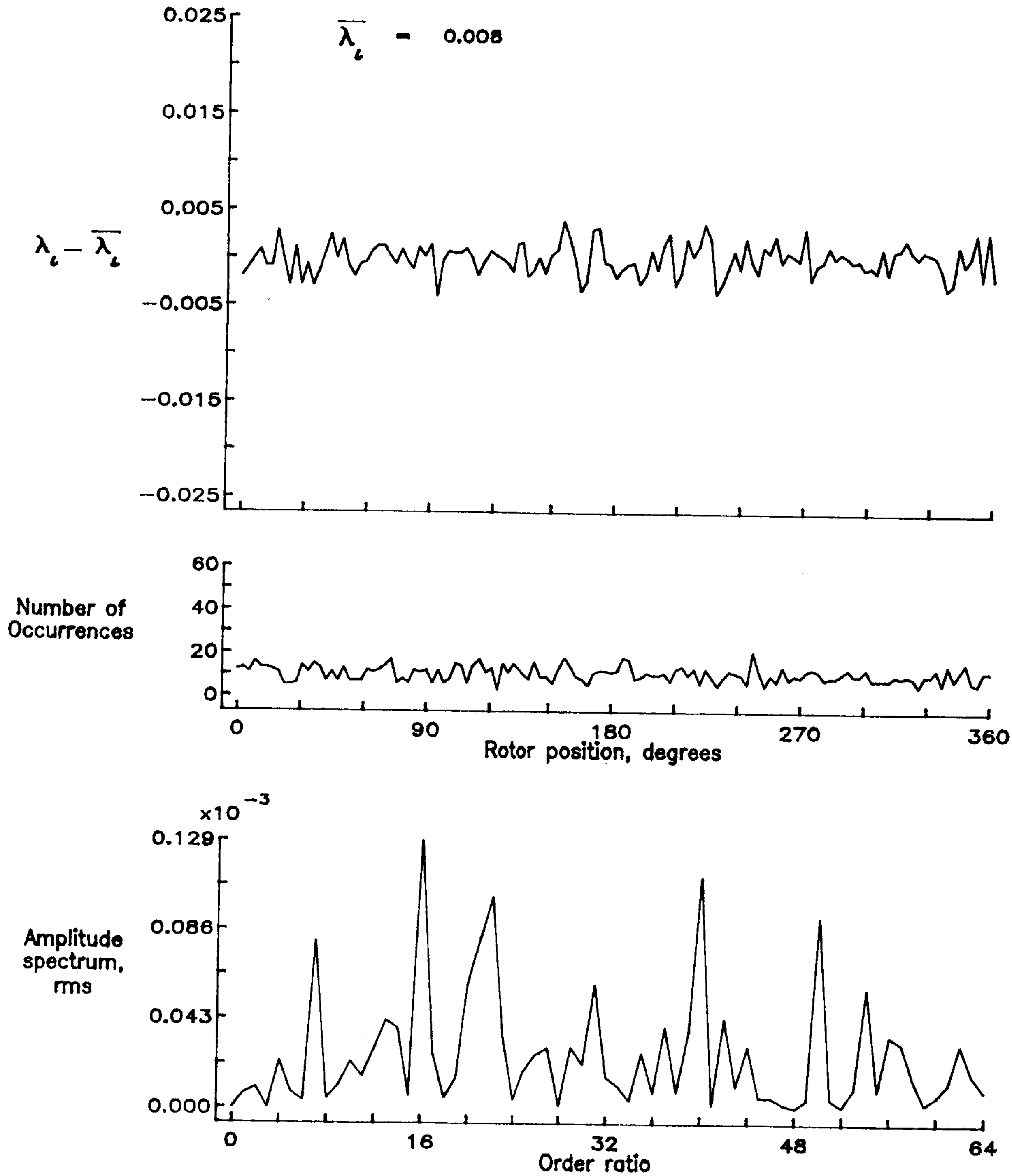


Figure 84.– Induced inflow velocity measured at 120 degrees and r/R of 0.98.



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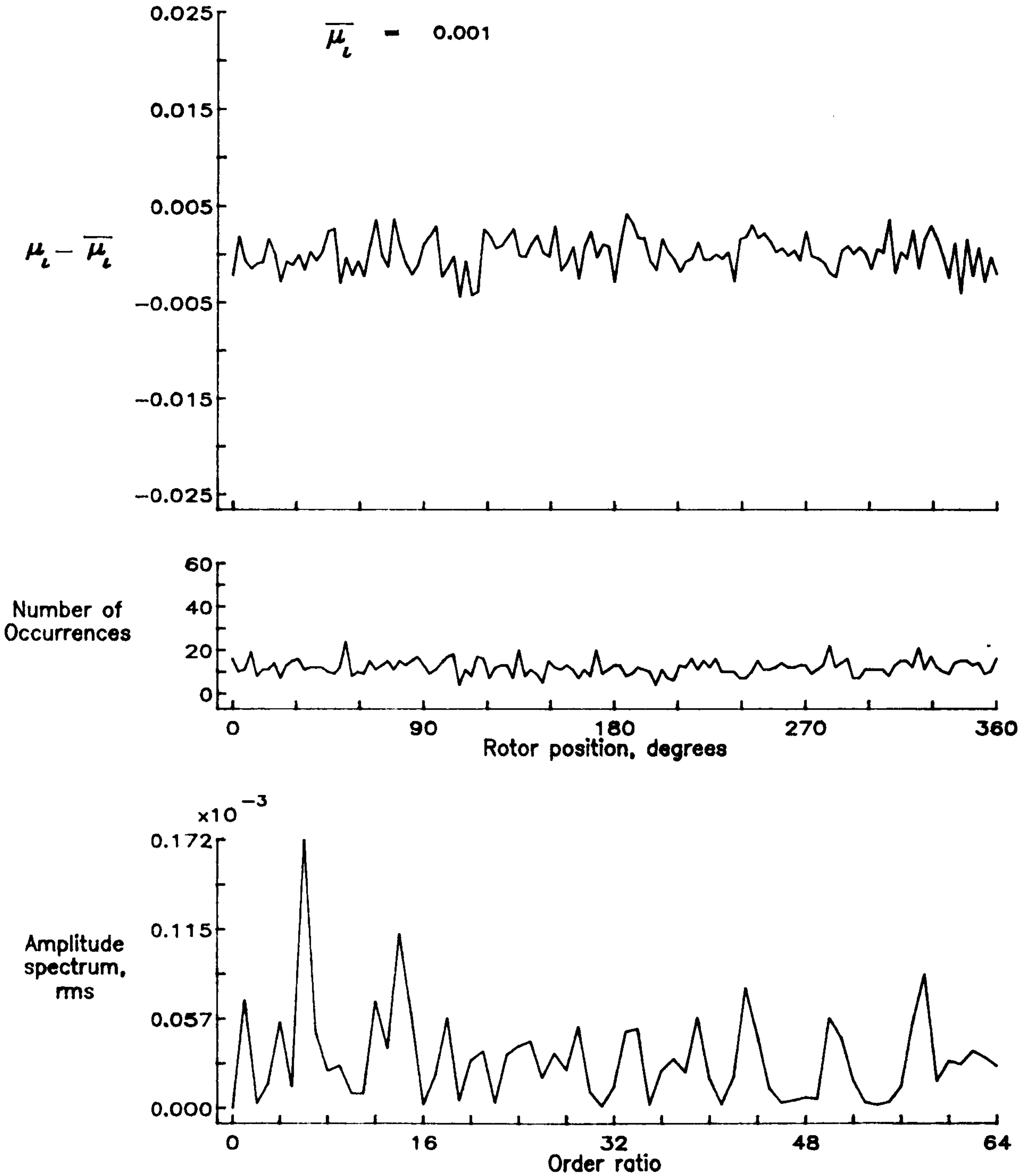


Figure 85.– Induced inflow velocity measured at 120 degrees and r/R of 1.02.

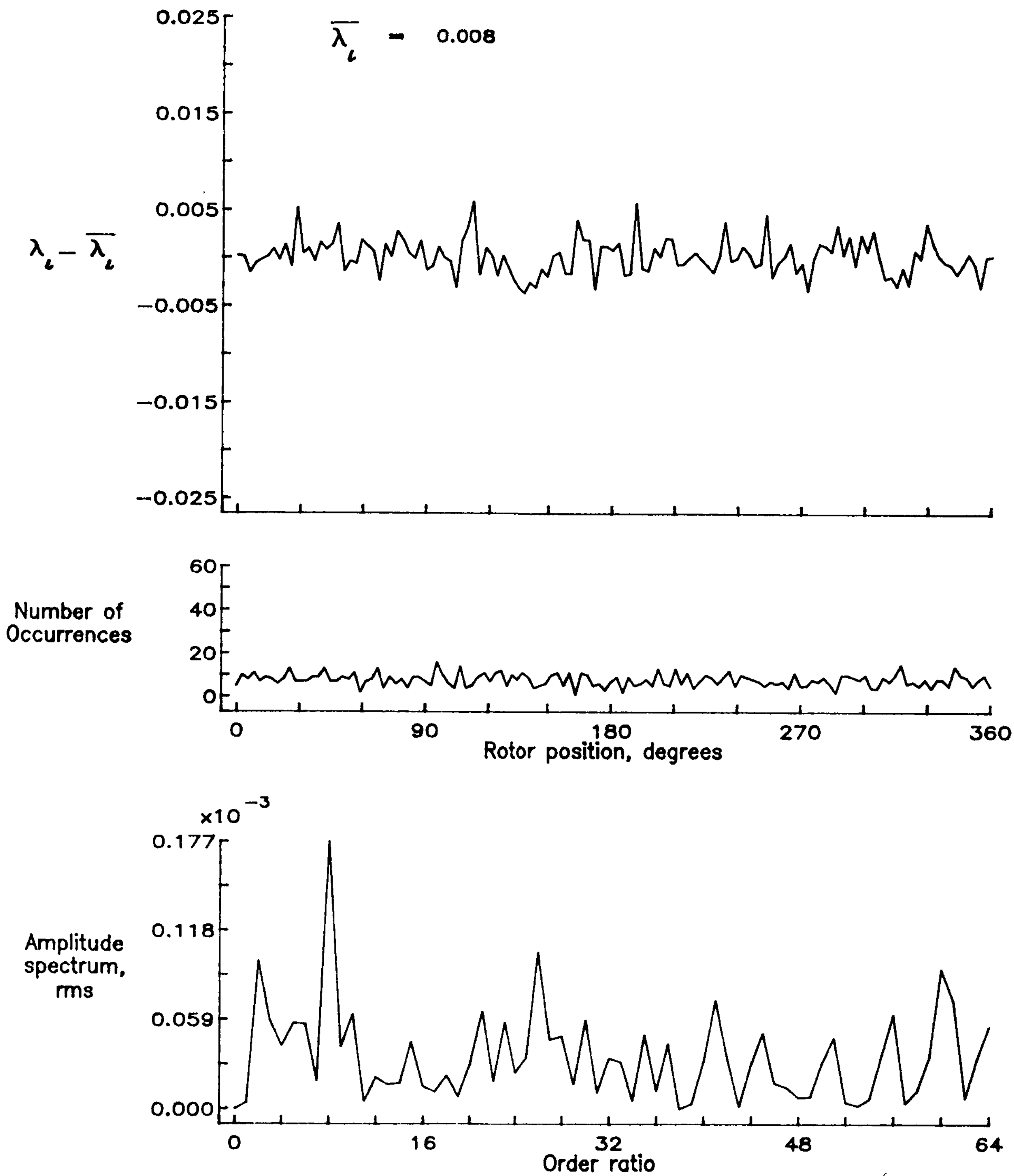


Figure 85.— Concluded.

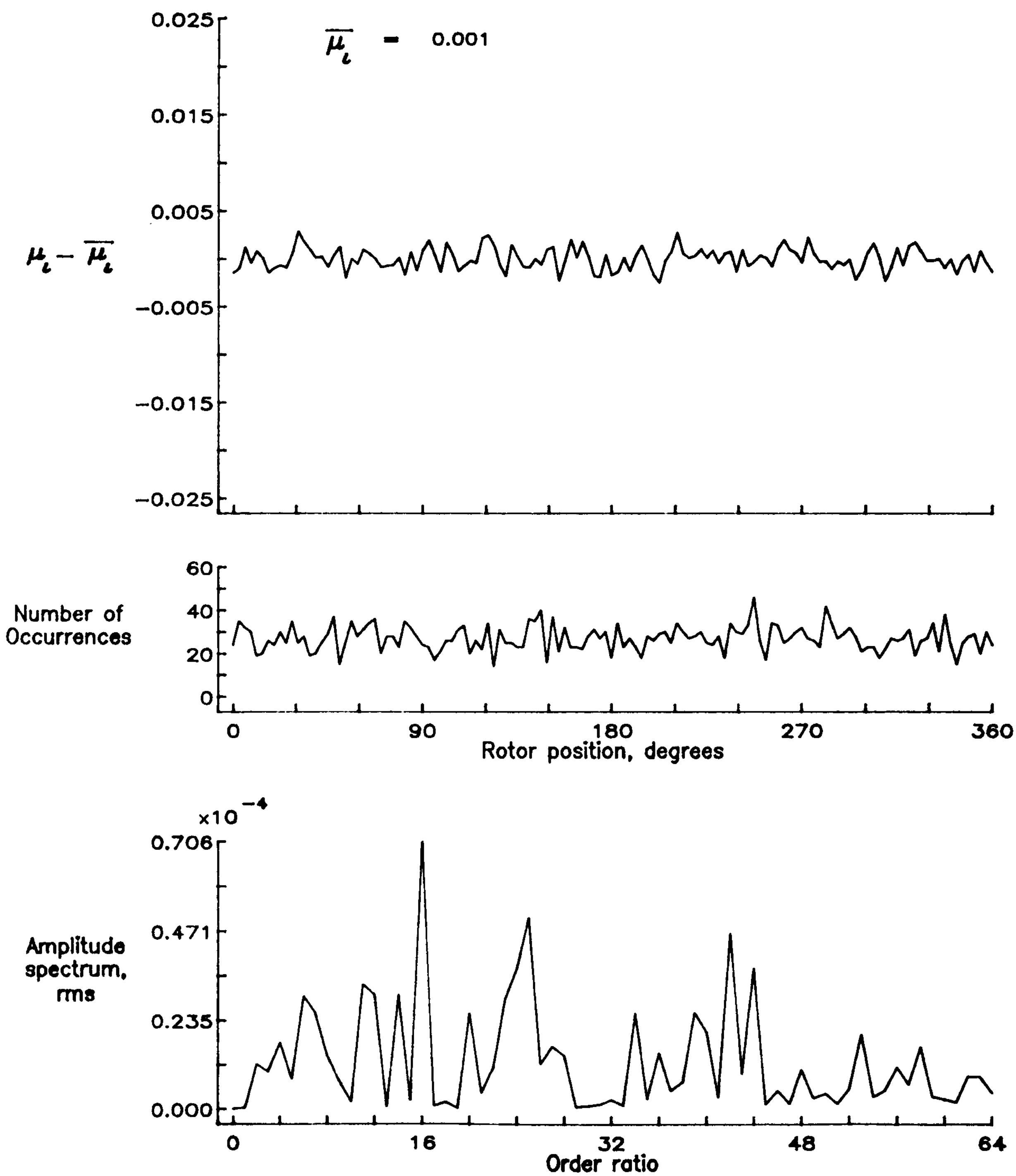


Figure 86.– Induced inflow velocity measured at 120 degrees and r/R of 1.04.

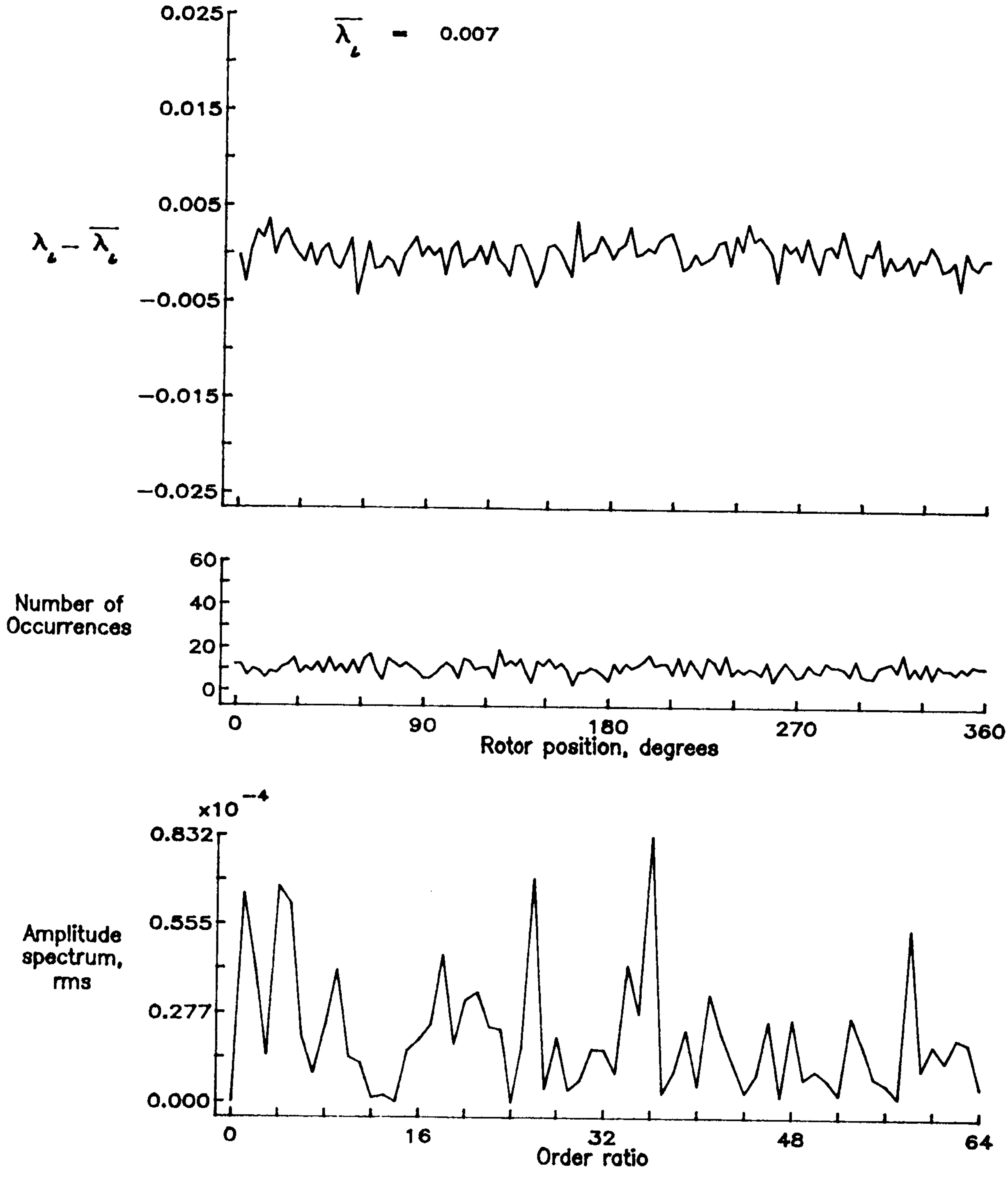


Figure 86.— Concluded.

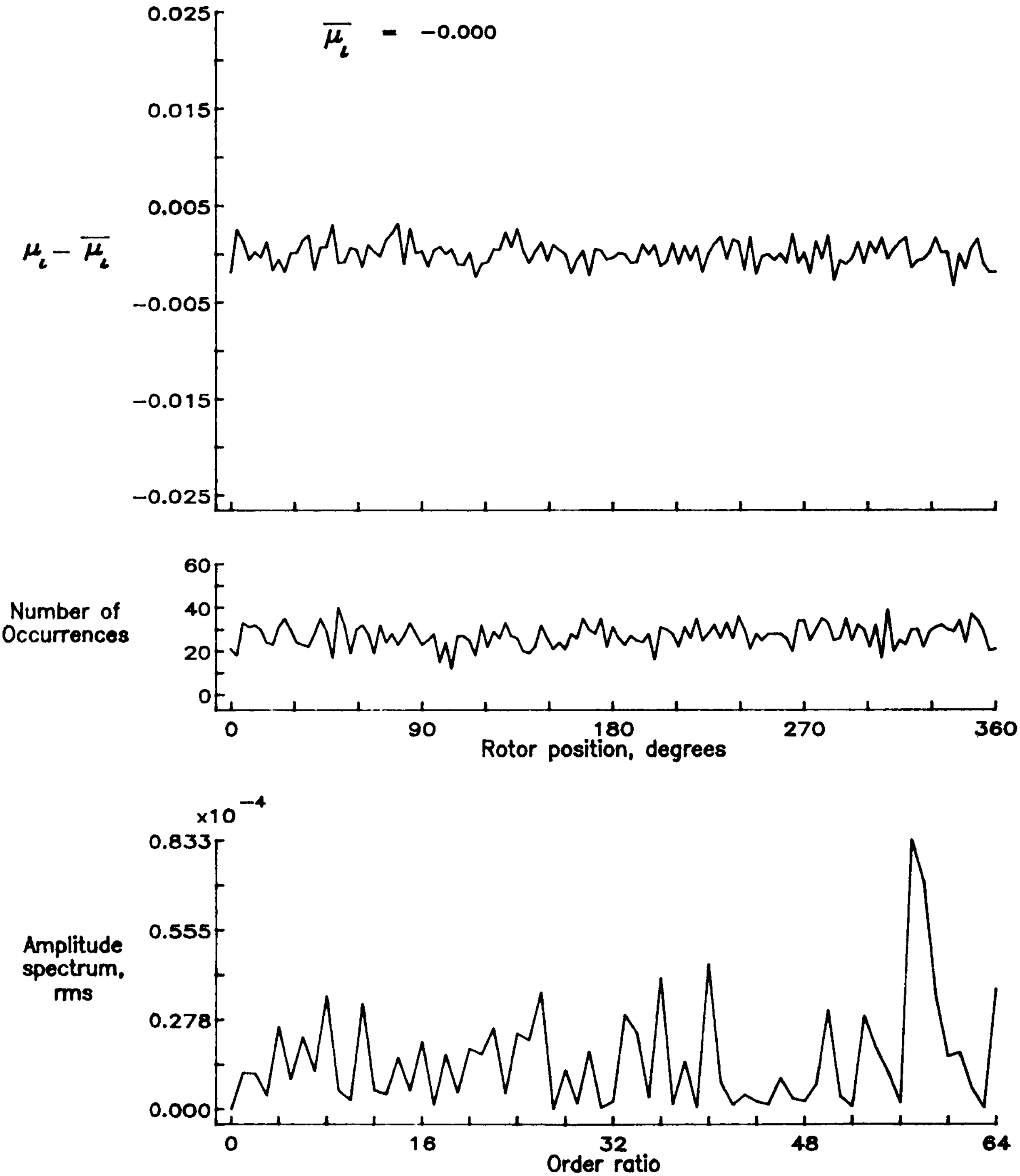


Figure 87.– Induced inflow velocity measured at 120 degrees and r/R of 1.10.

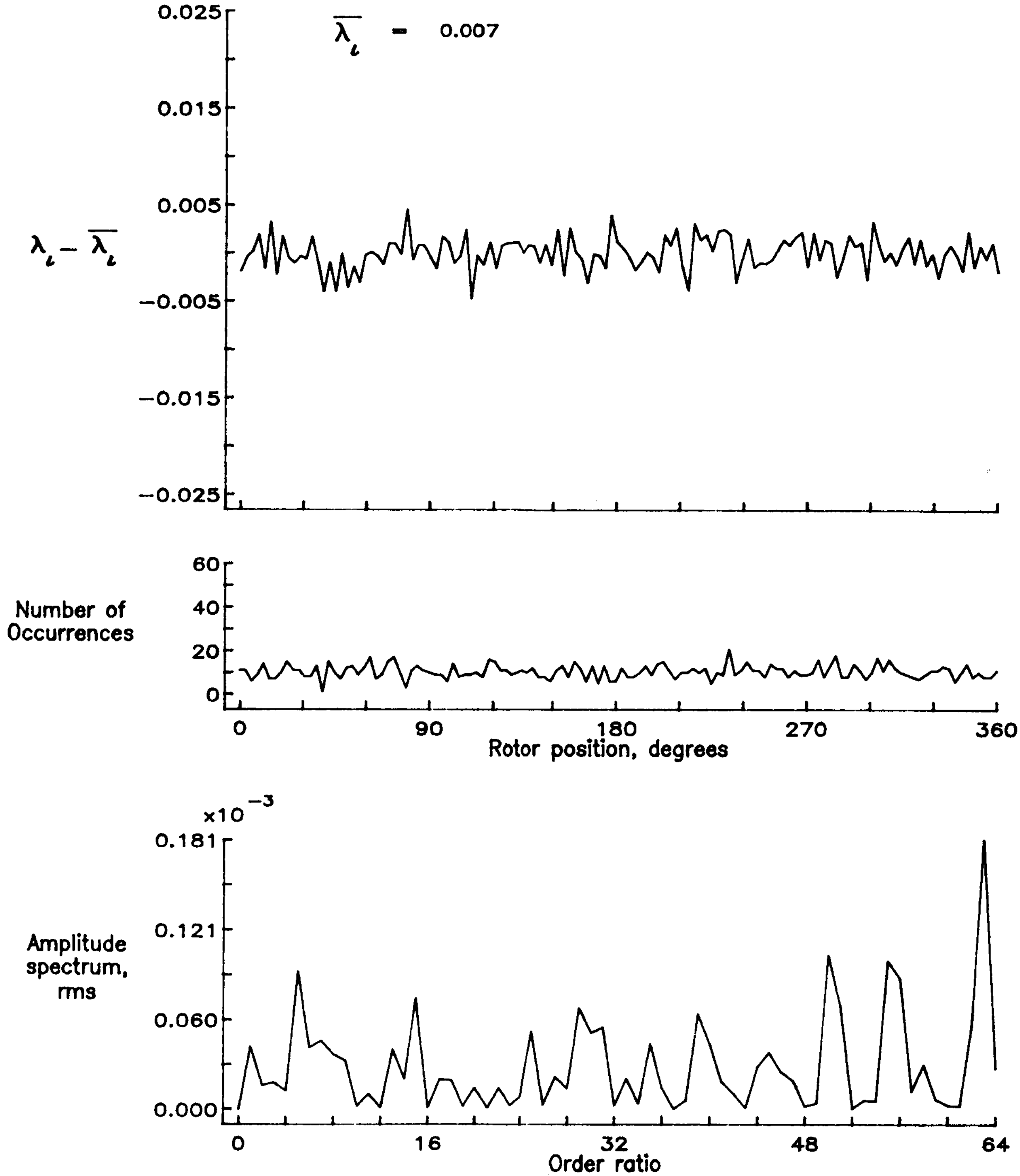


Figure 87.– Concluded.

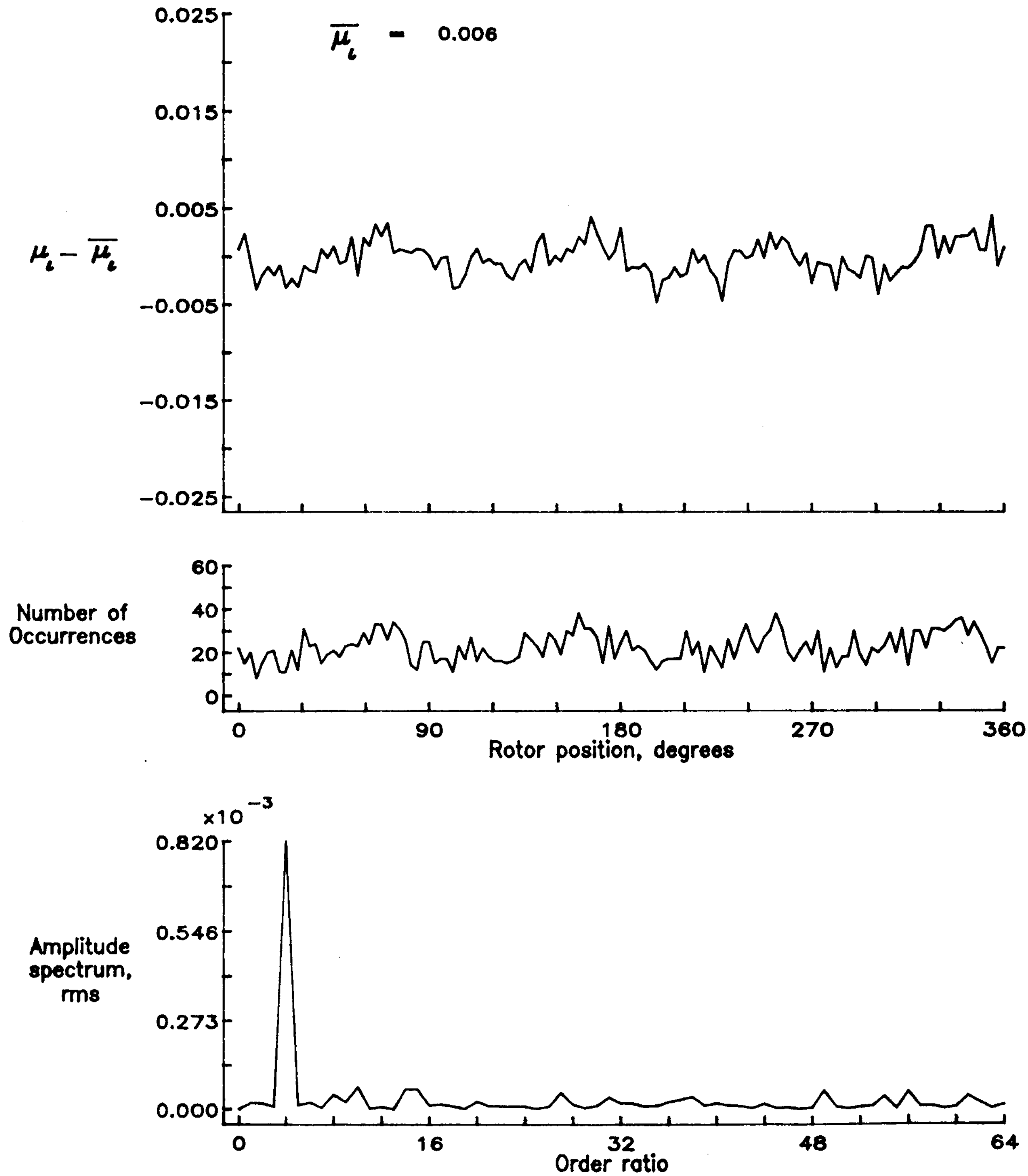
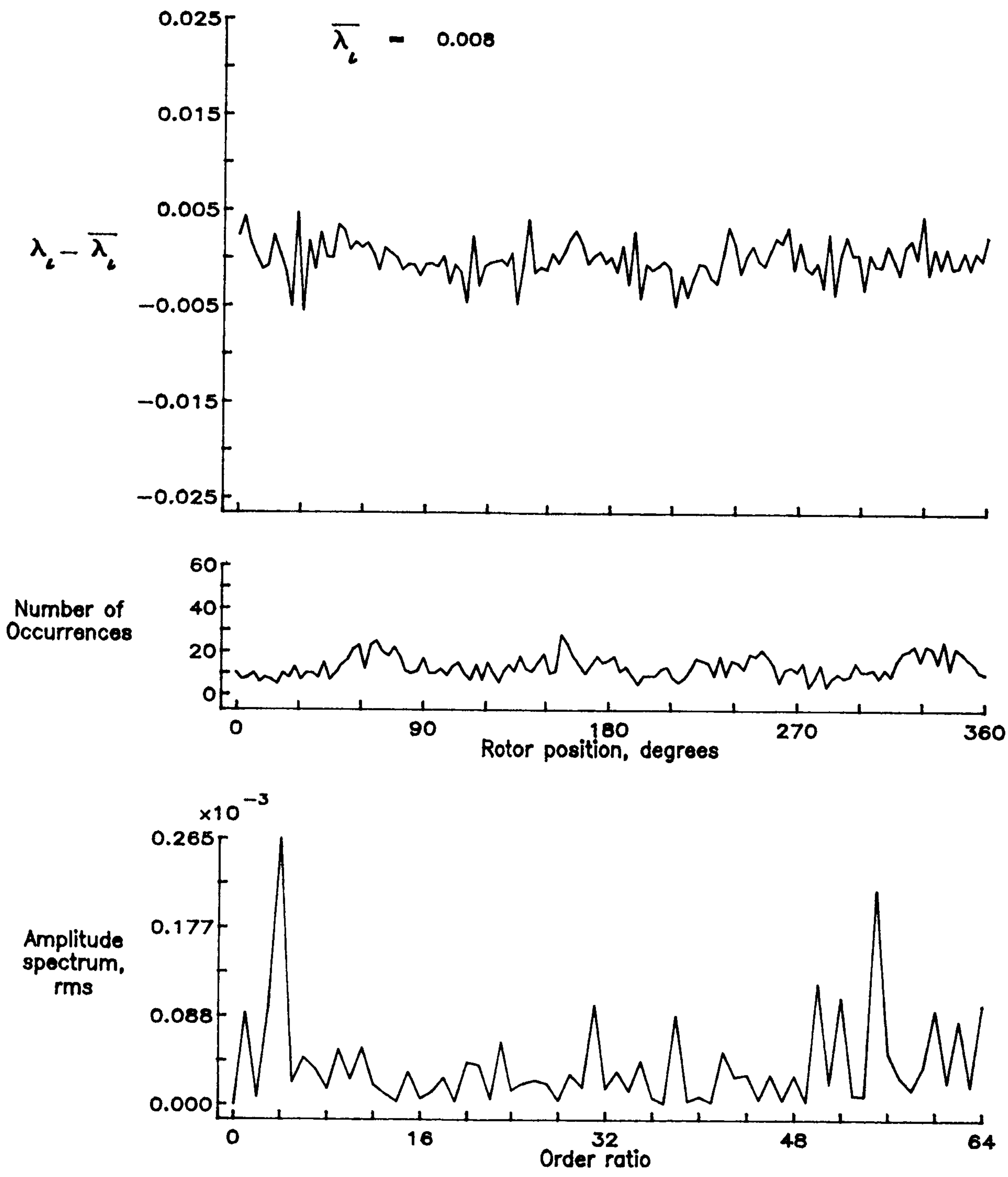


Figure 88.– Induced inflow velocity measured at 150 degrees and r/R of 0.20.



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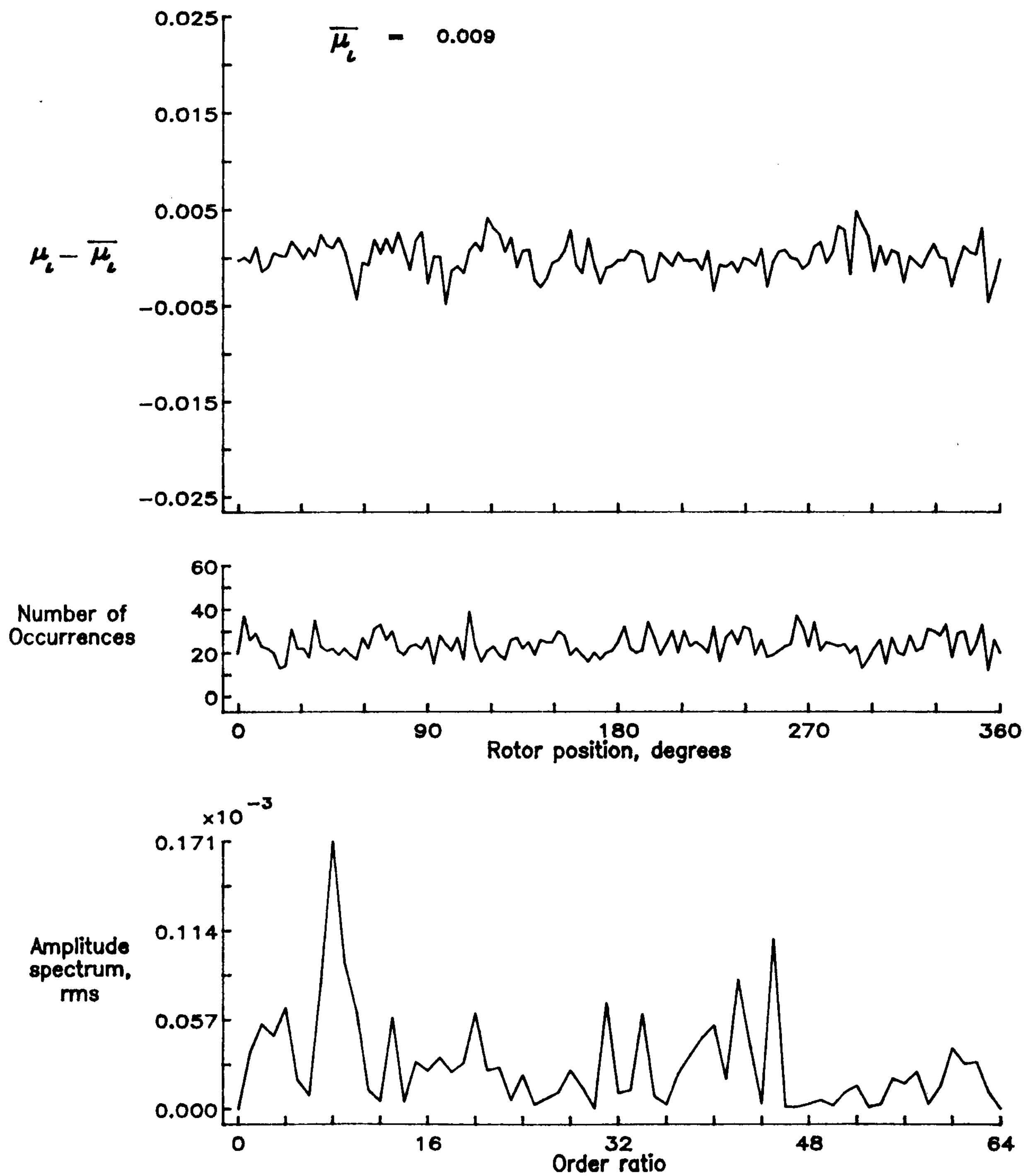


Figure 89.– Induced inflow velocity measured at 150 degrees and r/R of 0.40.

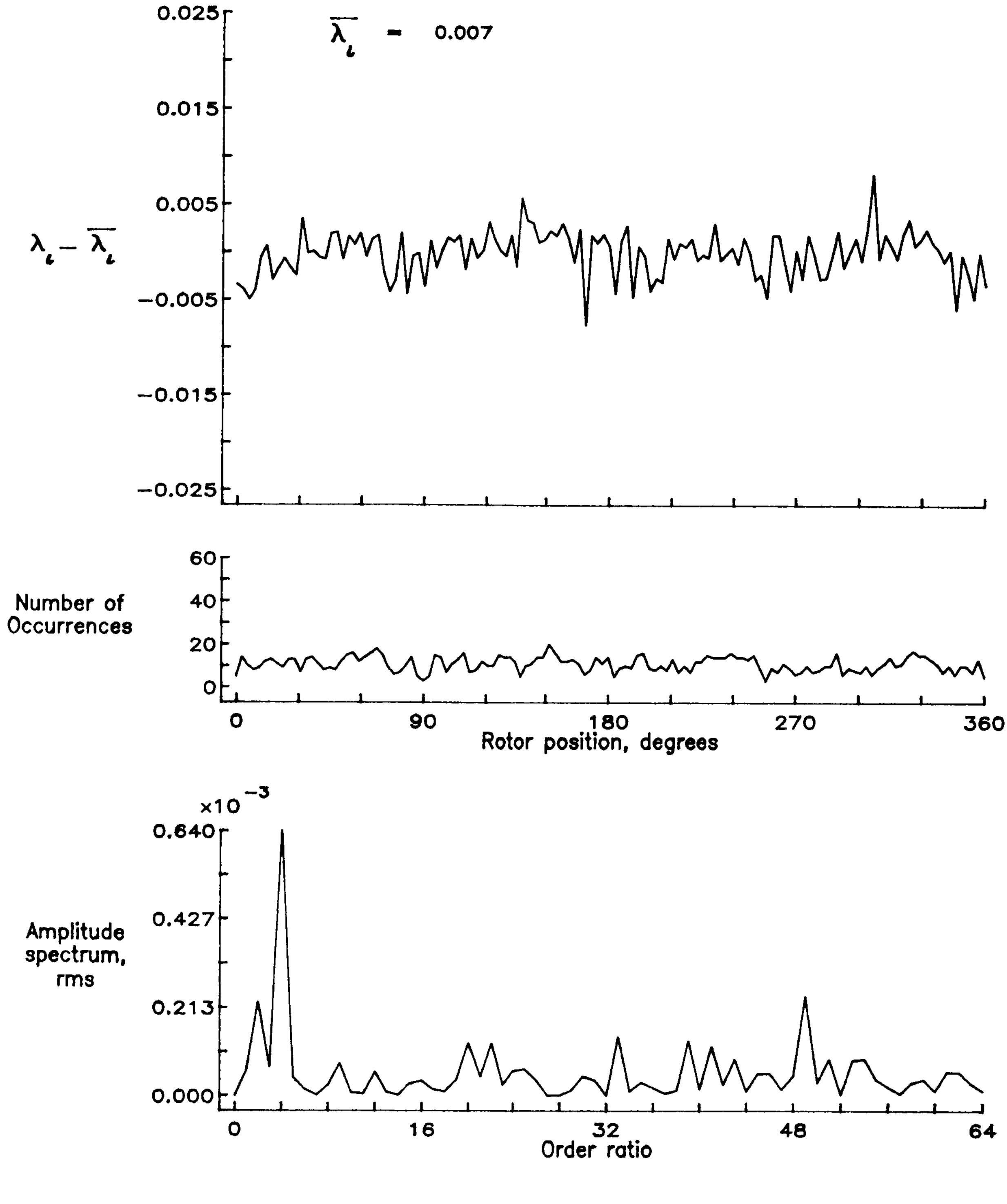


Figure 89.– Concluded.

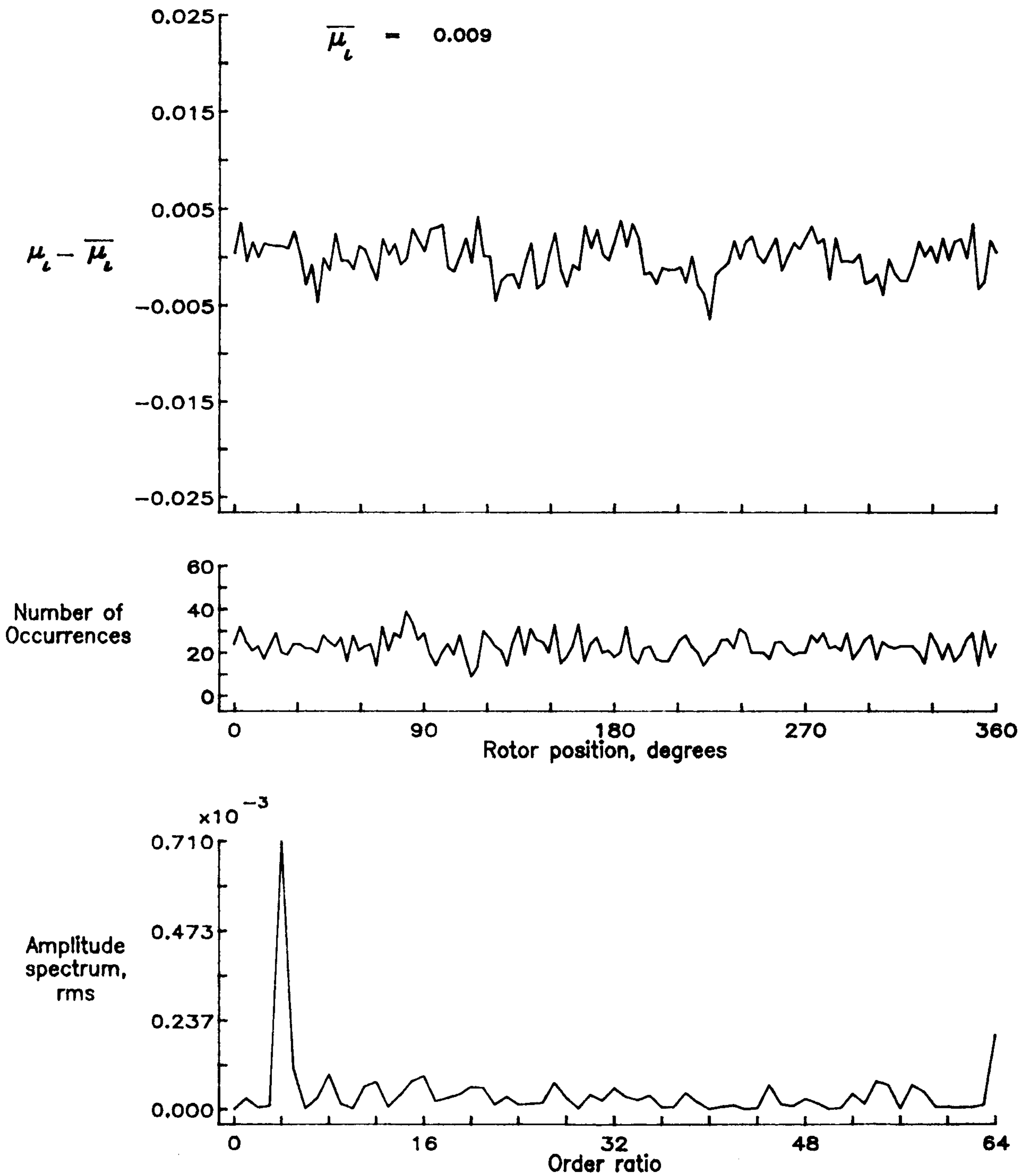
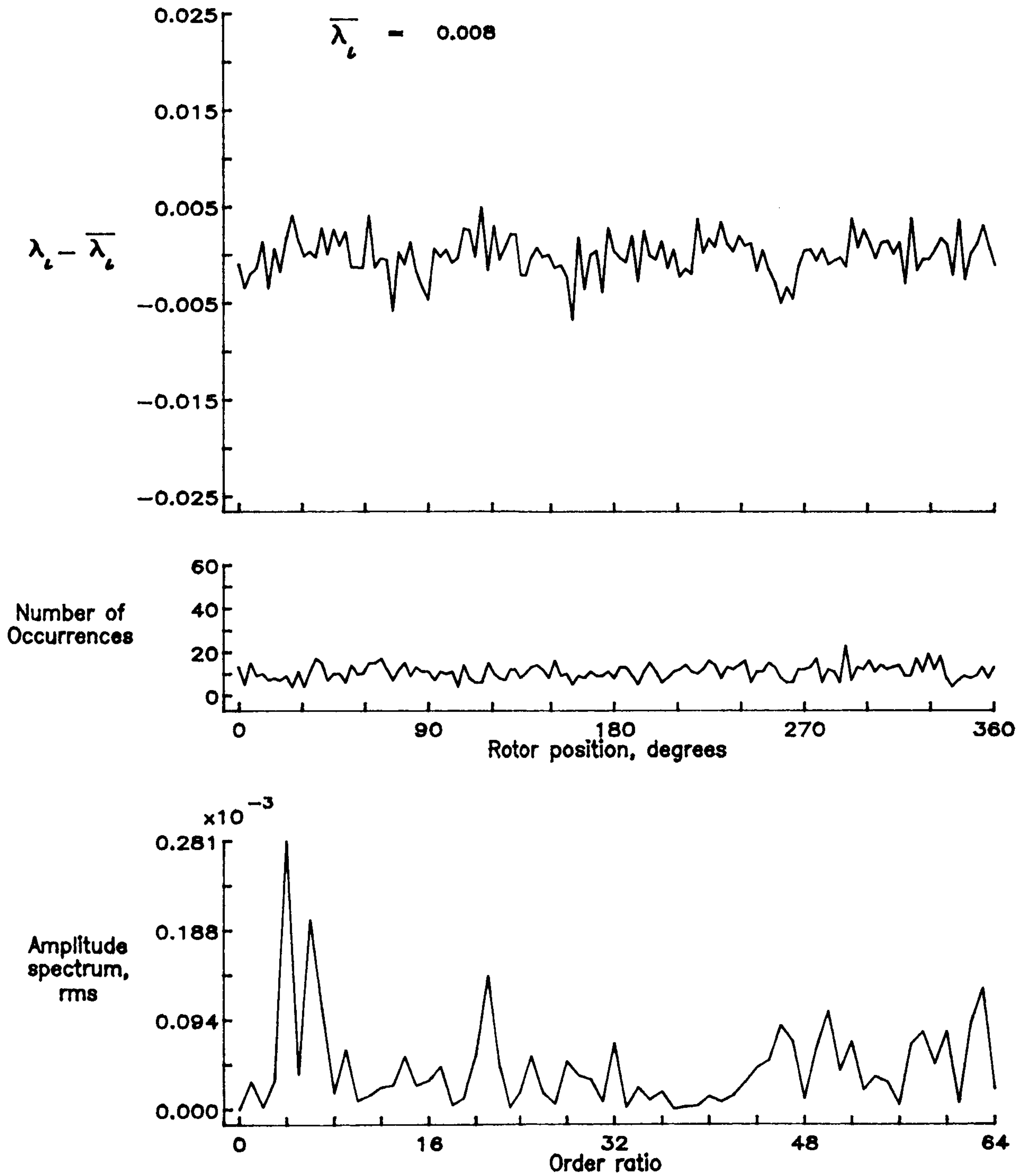


Figure 90.— Induced inflow velocity measured at 150 degrees and r/R of 0.50.



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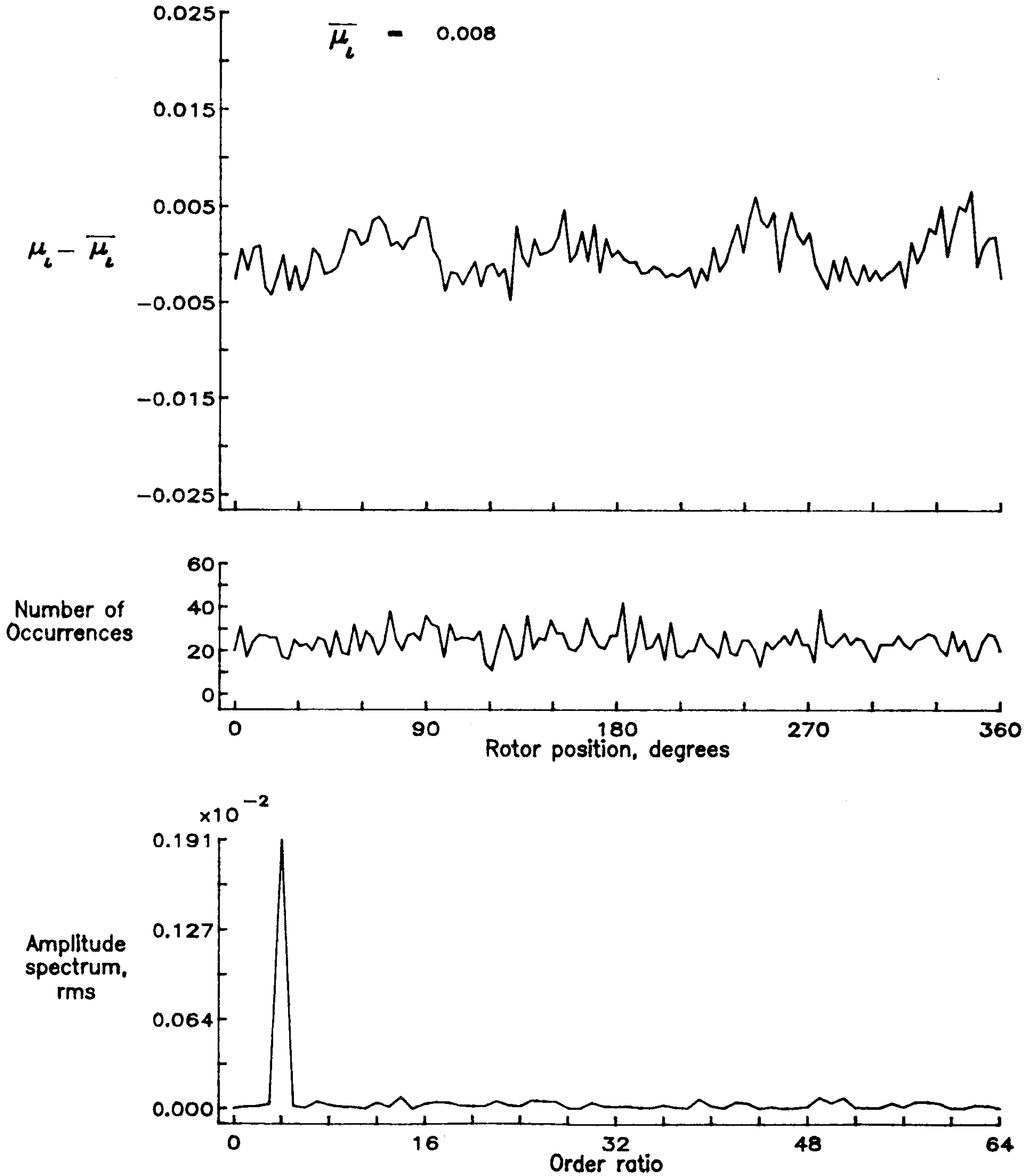
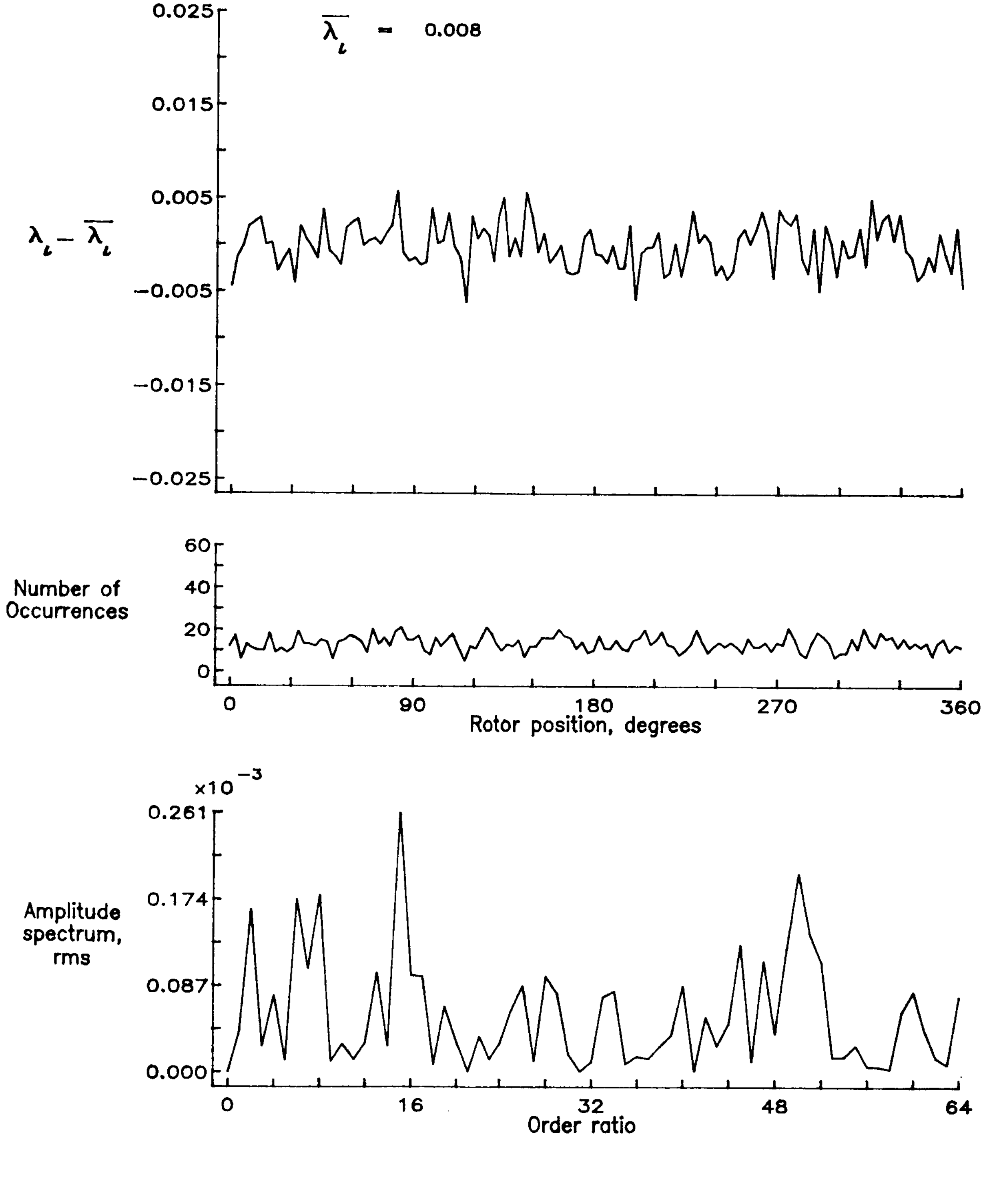


Figure 91.– Induced inflow velocity measured at 150 degrees and r/R of 0.60.



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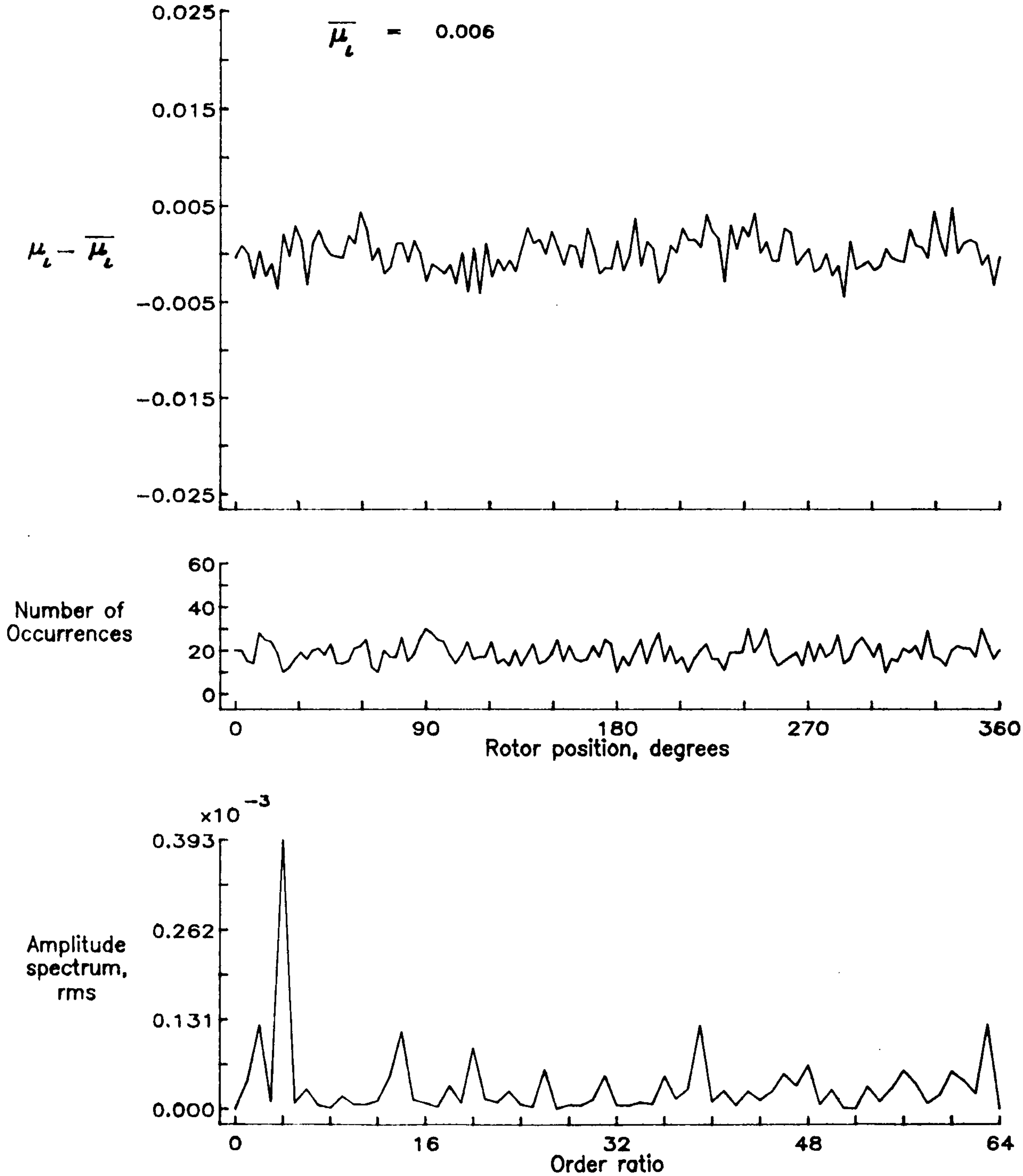
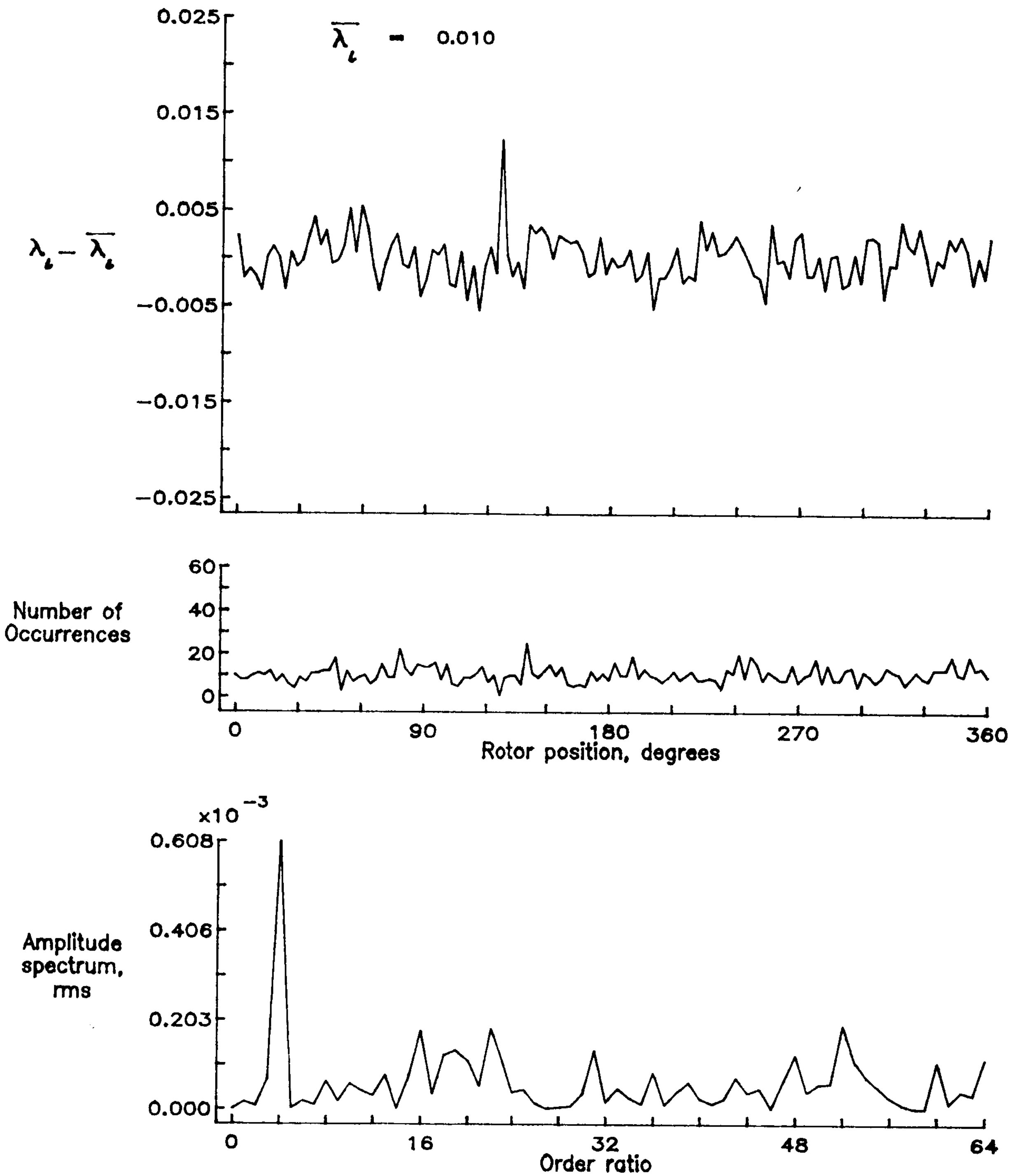


Figure 92.– Induced inflow velocity measured at 150 degrees and r/R of 0.70.



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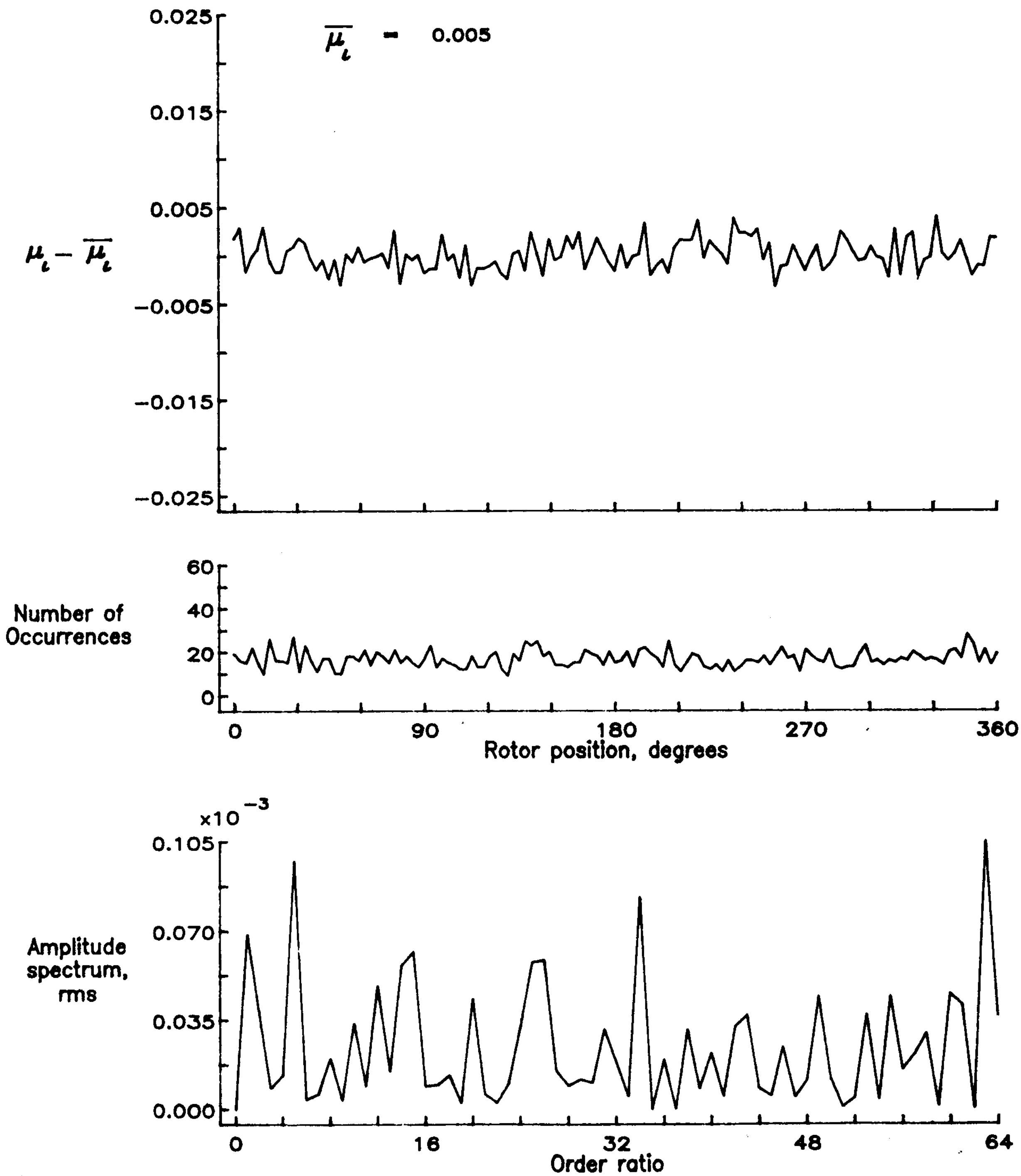
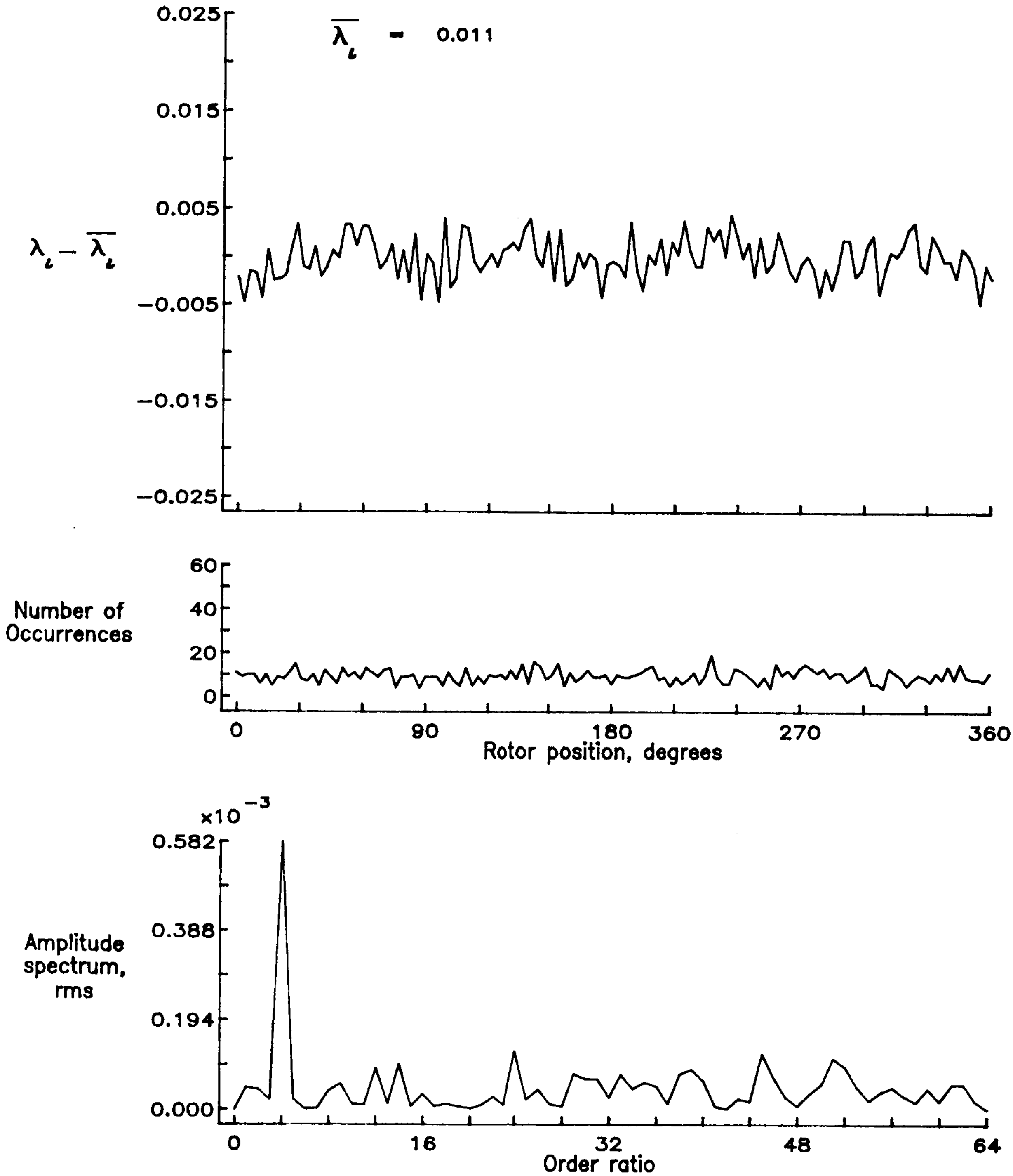


Figure 93.– Induced inflow velocity measured at 150 degrees and r/R of 0.74.



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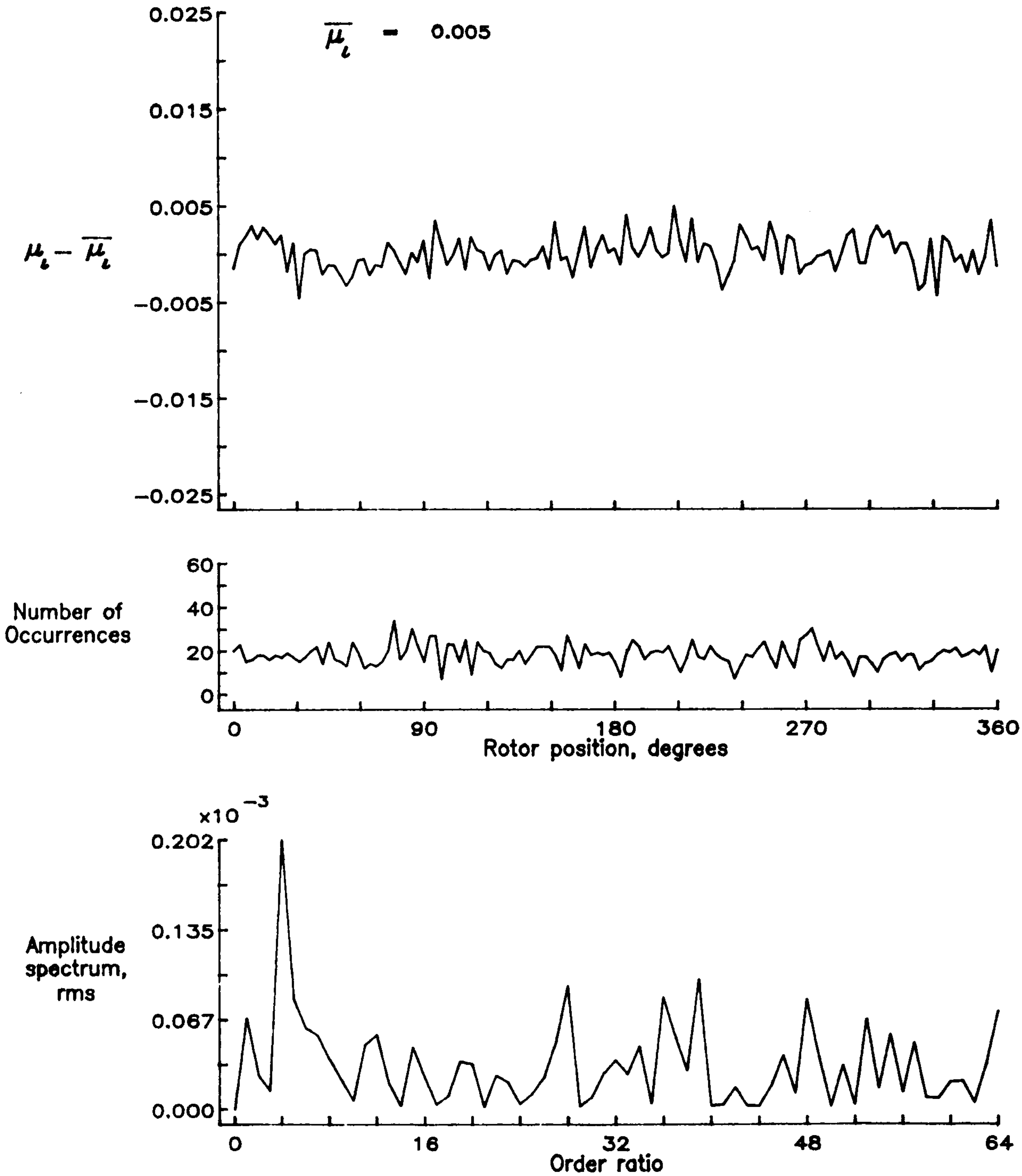
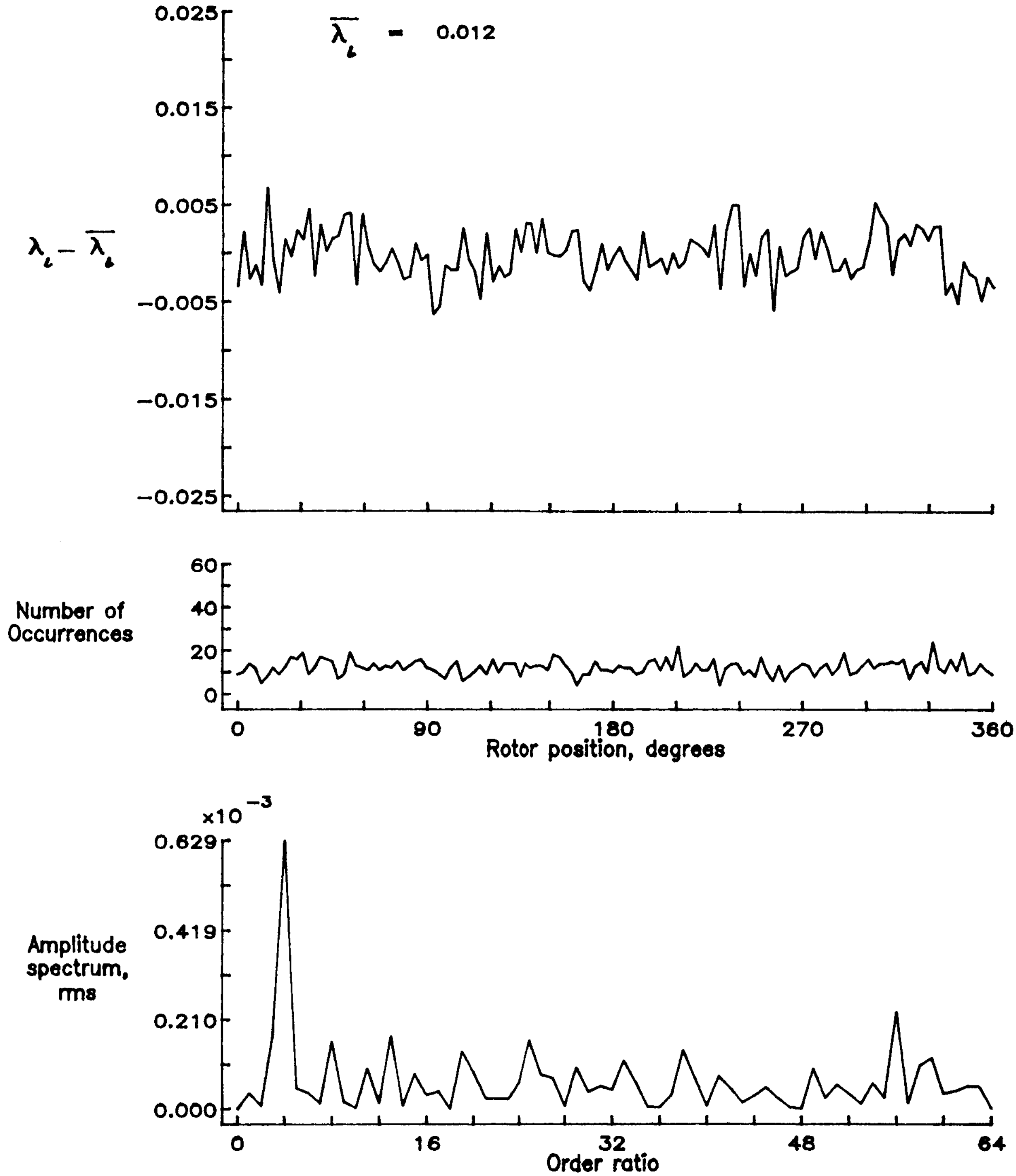


Figure 94.– Induced inflow velocity measured at 150 degrees and r/R of 0.78.



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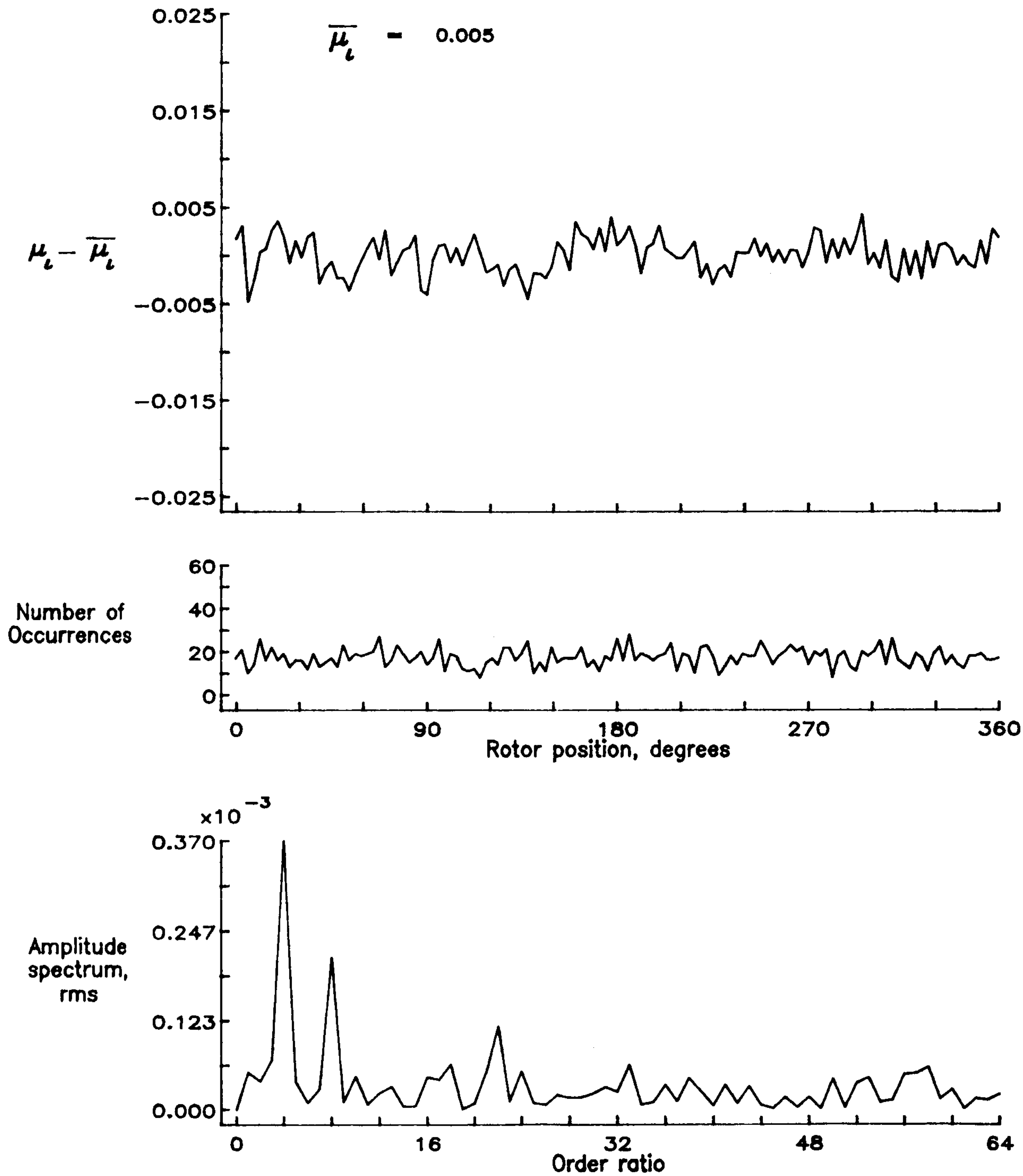
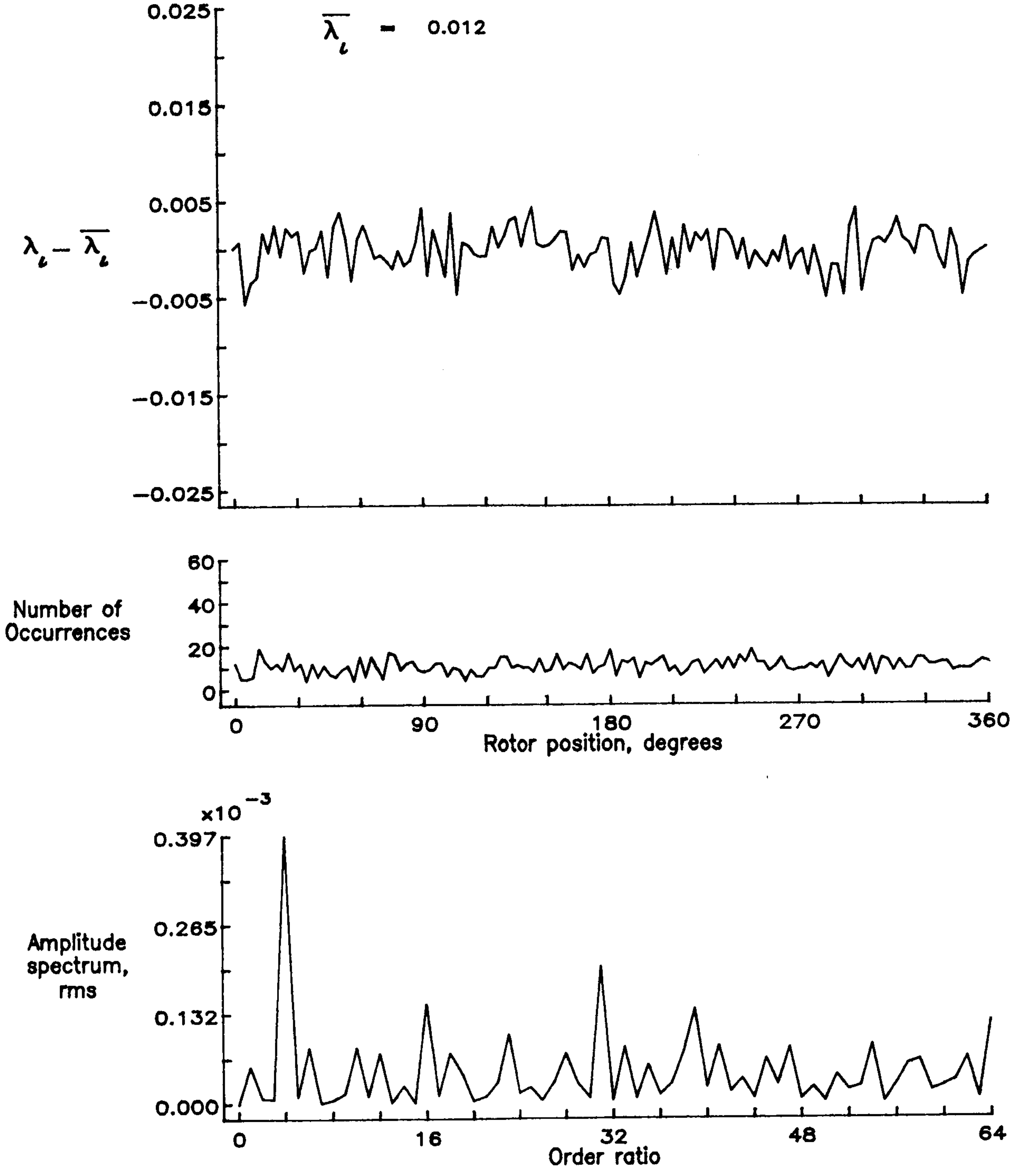


Figure 95.– Induced inflow velocity measured at 150 degrees and r/R of 0.82.



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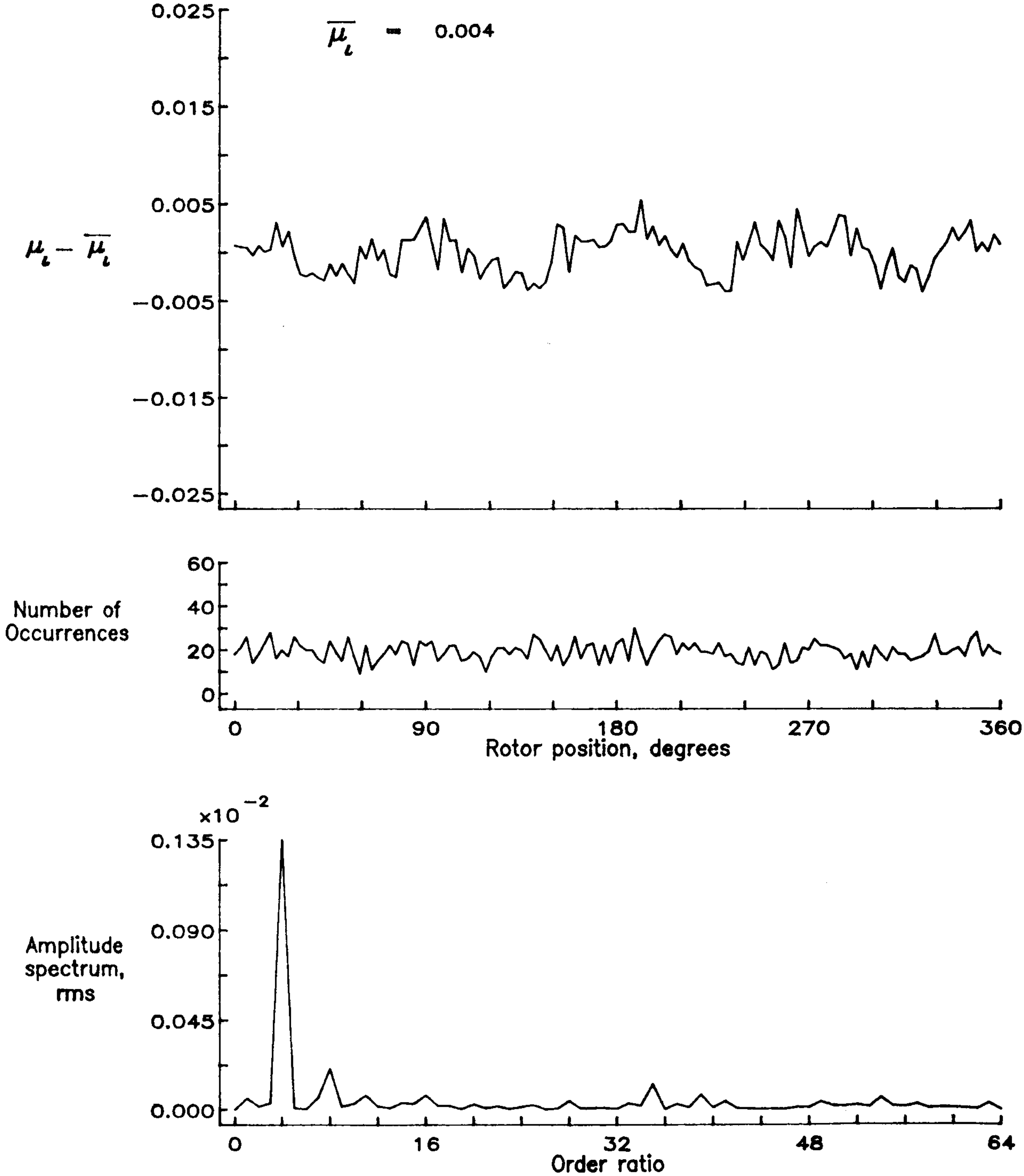
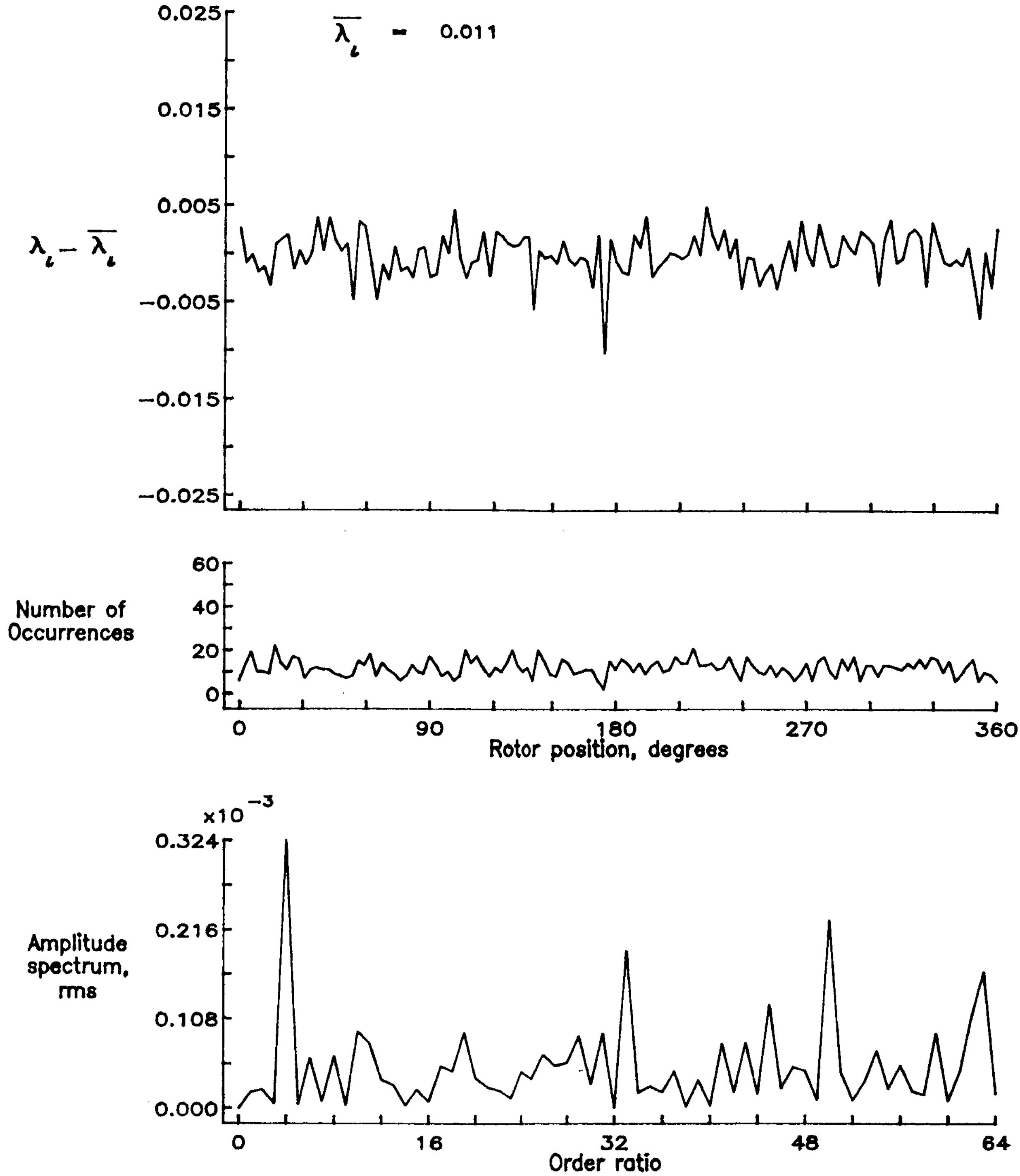


Figure 96.– Induced inflow velocity measured at 150 degrees and r/R of 0.86.



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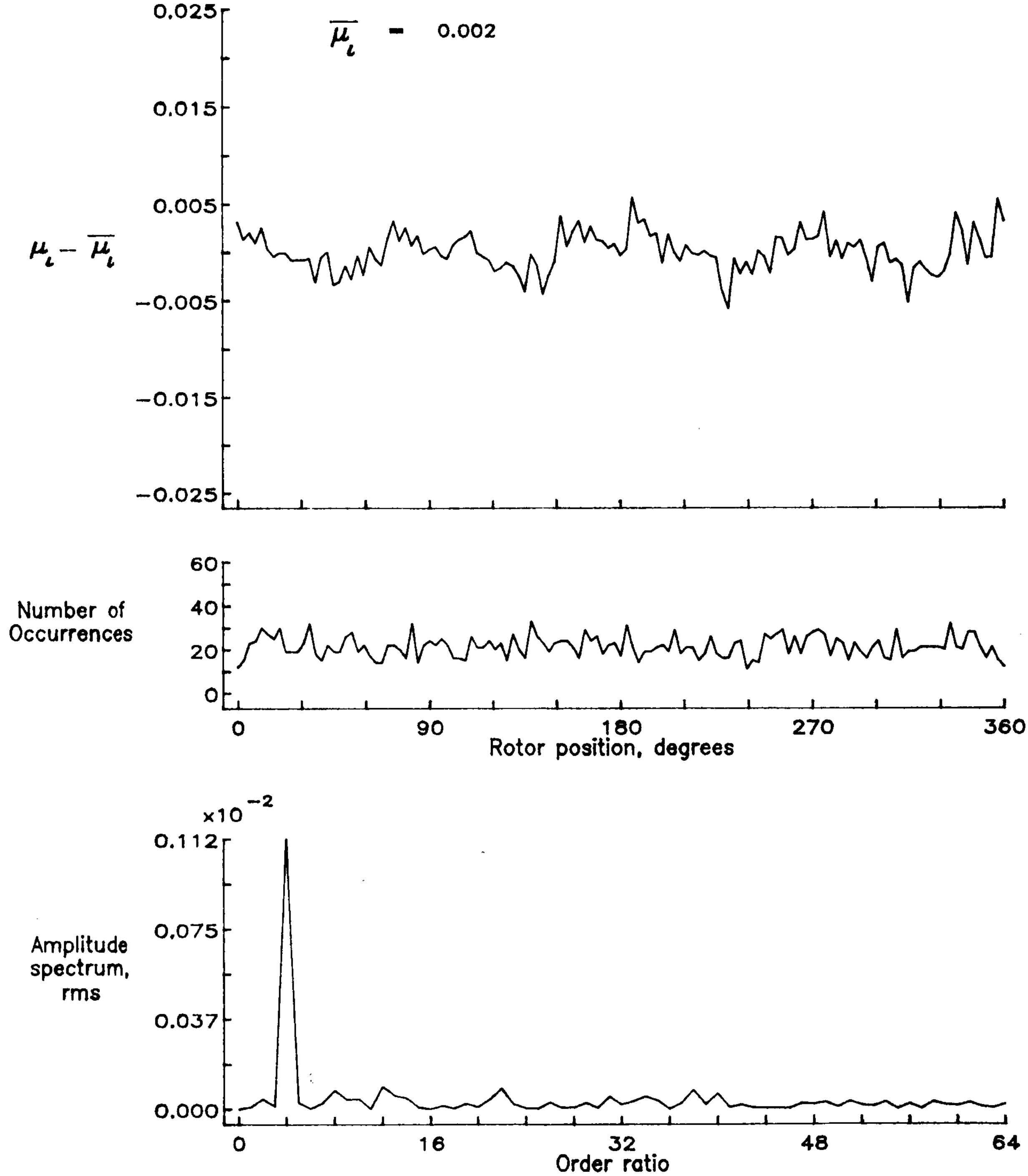
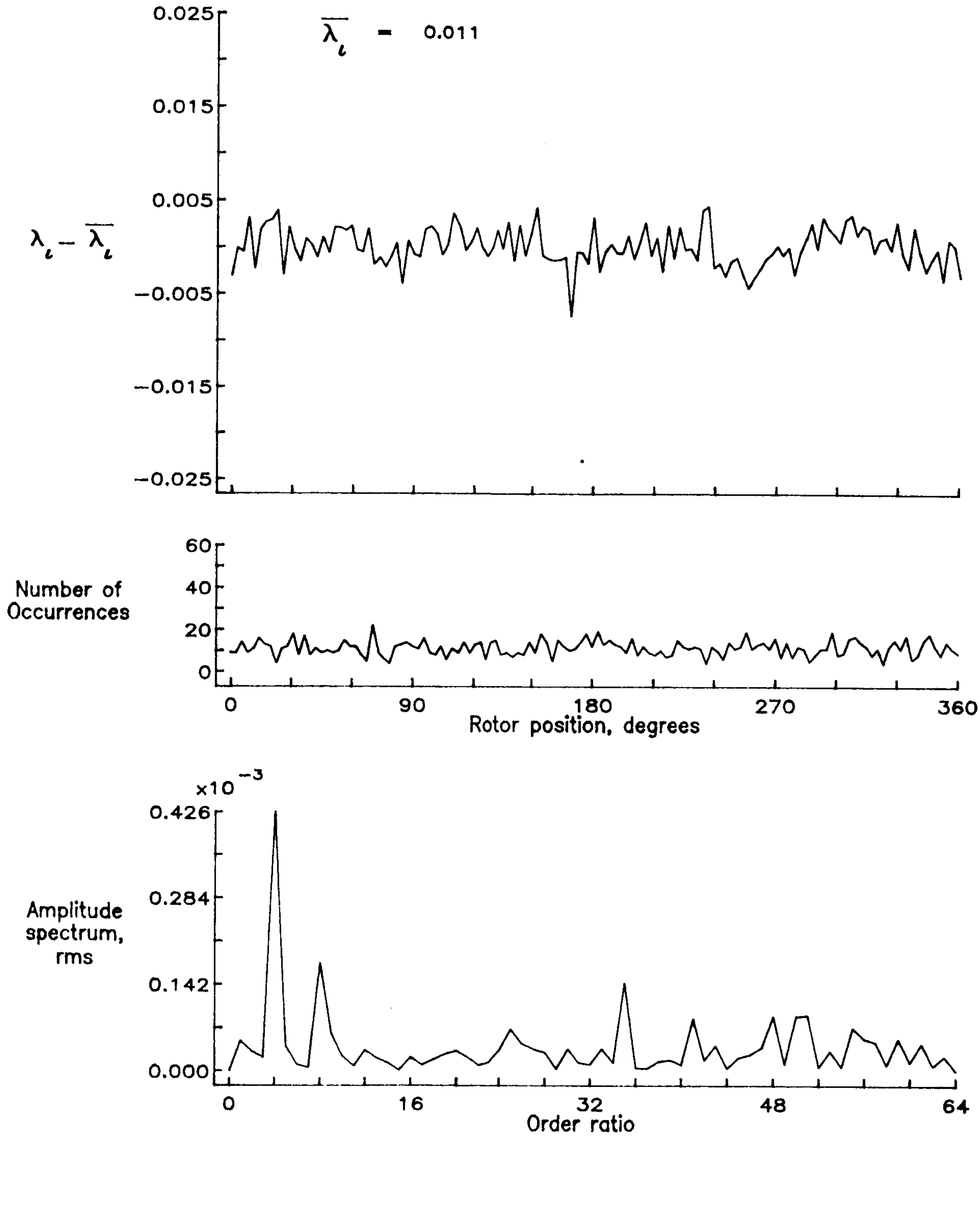


Figure 97.– Induced inflow velocity measured at 150 degrees and r/R of 0.90.



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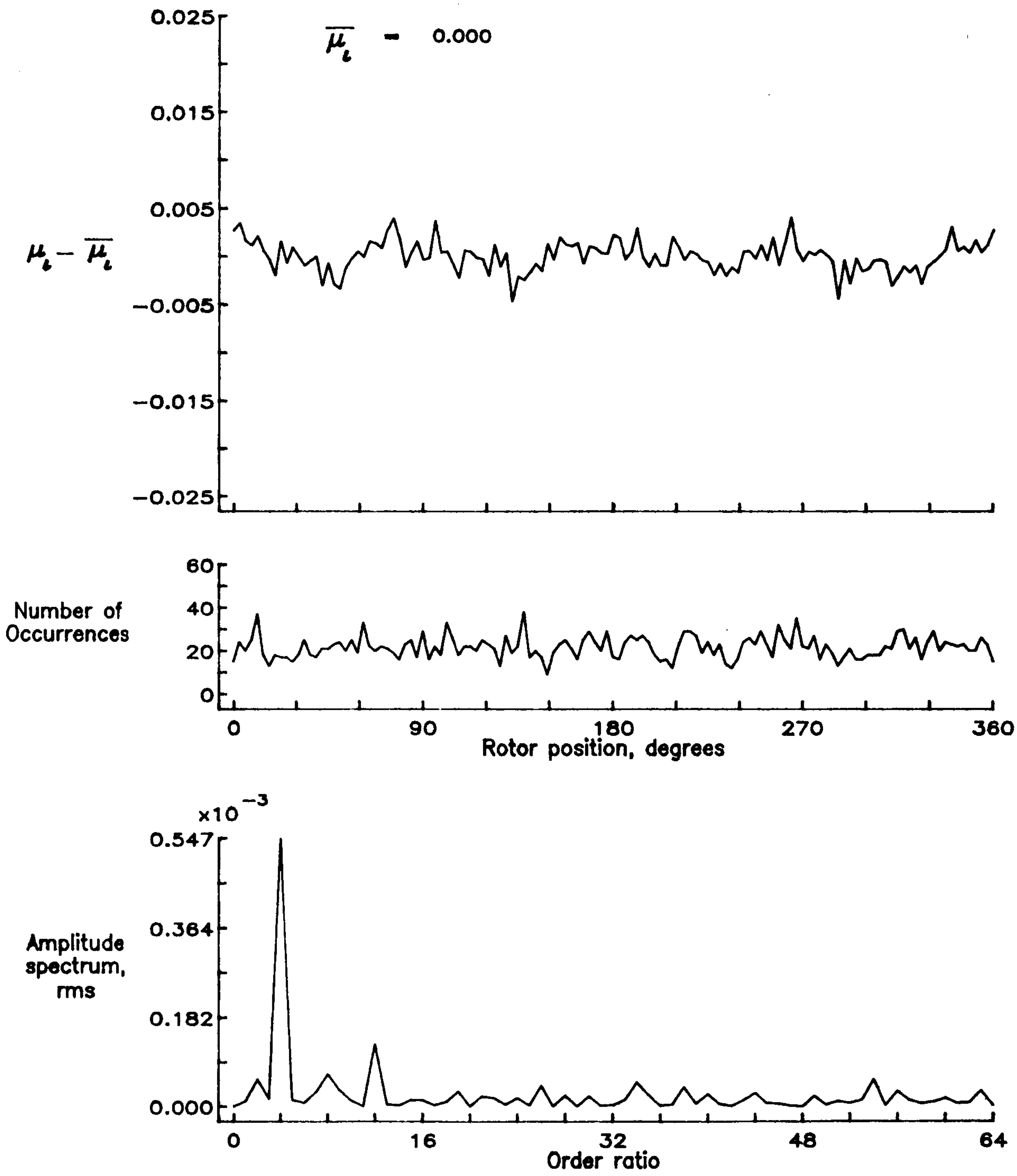
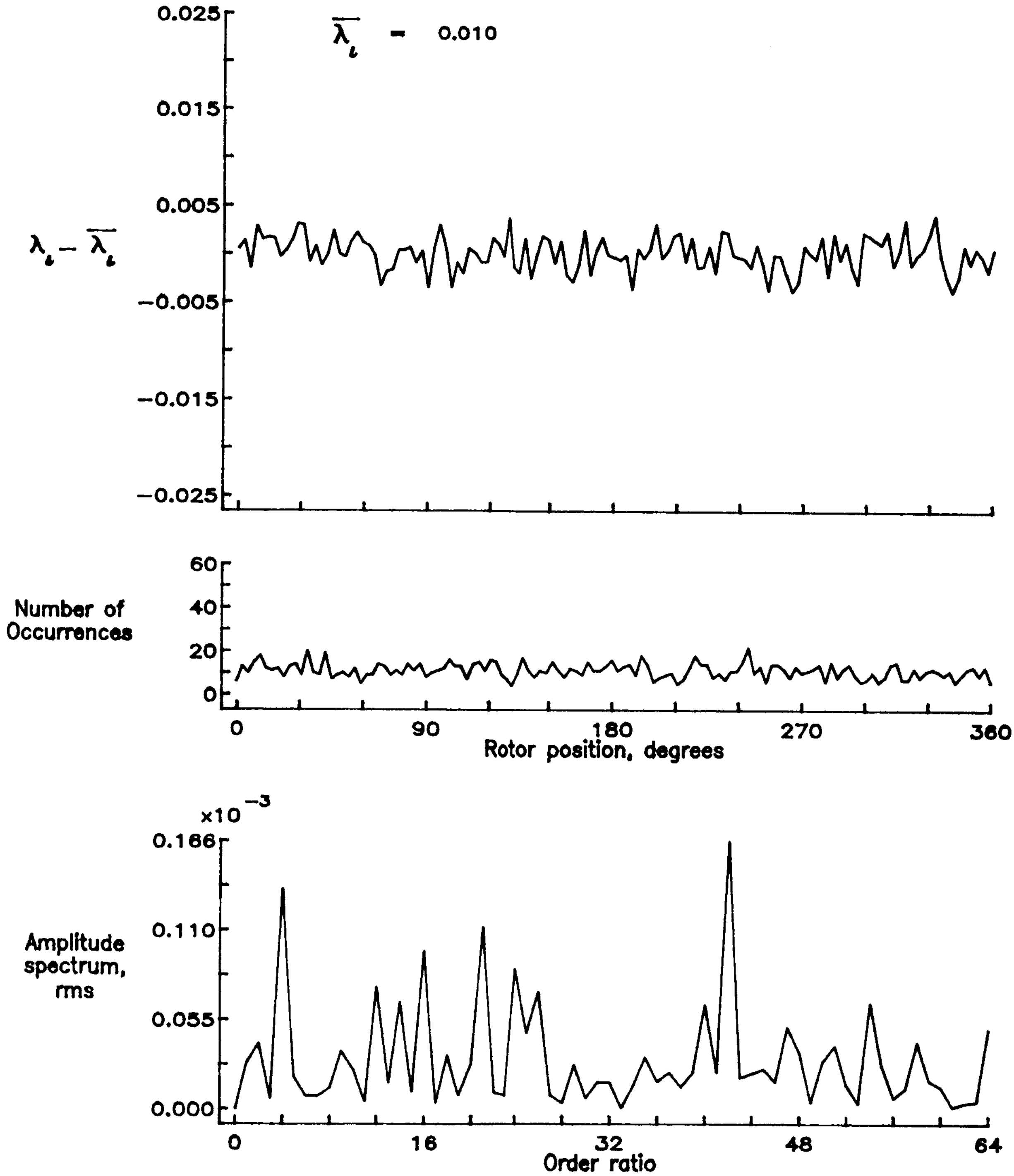


Figure 98.– Induced inflow velocity measured at 150 degrees and r/R of 0.94.



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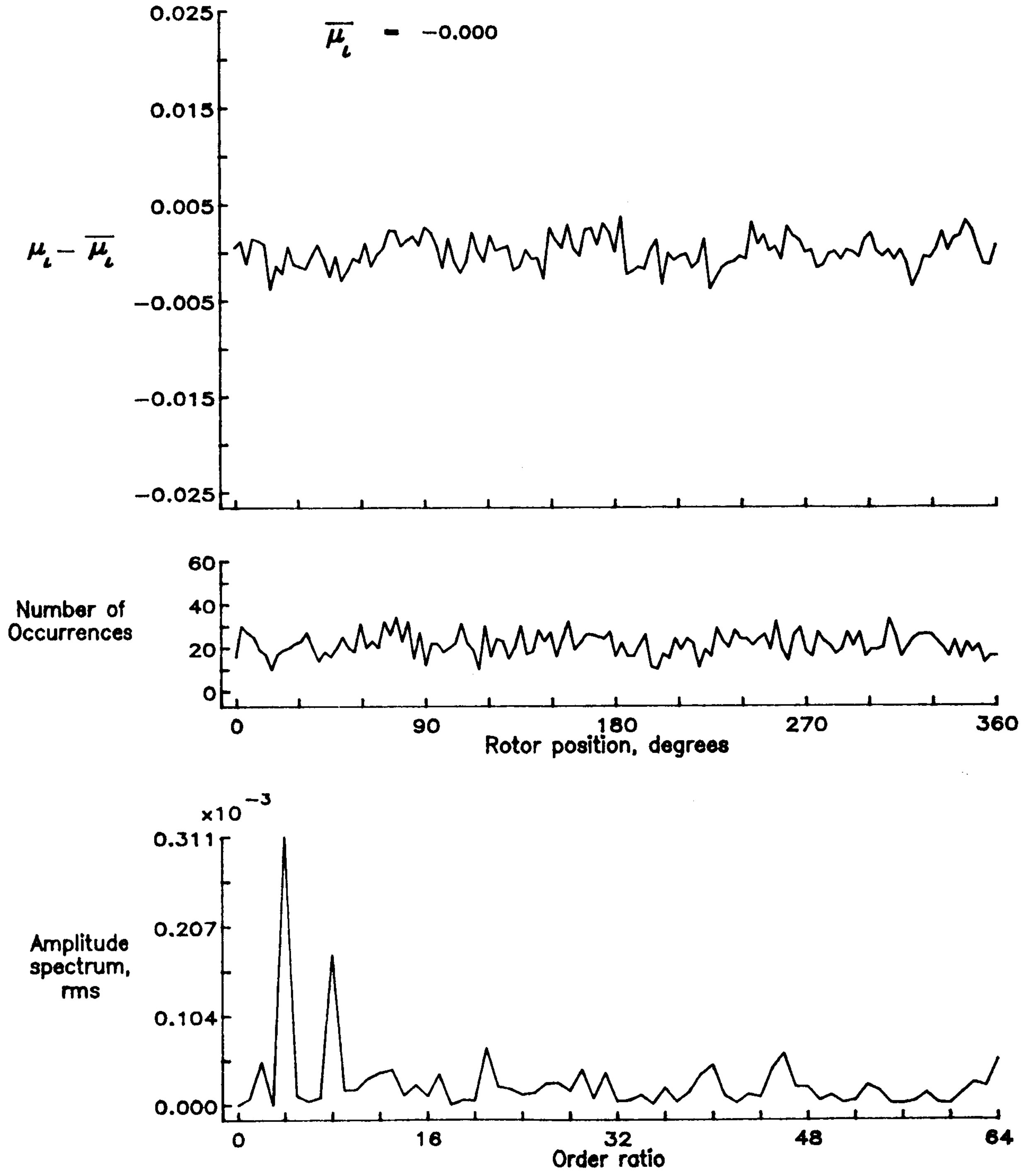
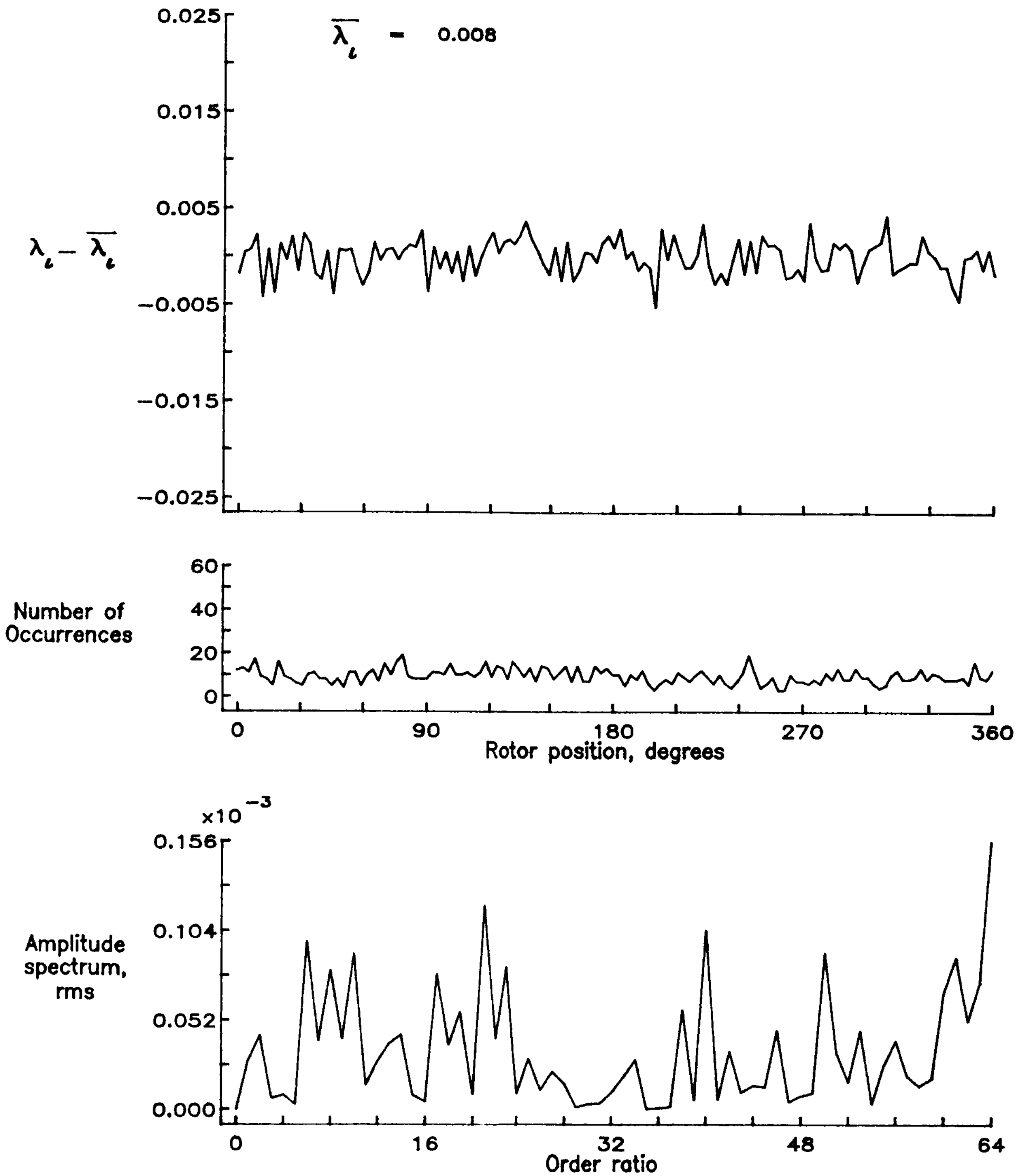


Figure 99.– Induced inflow velocity measured at 150 degrees and r/R of 0.98.



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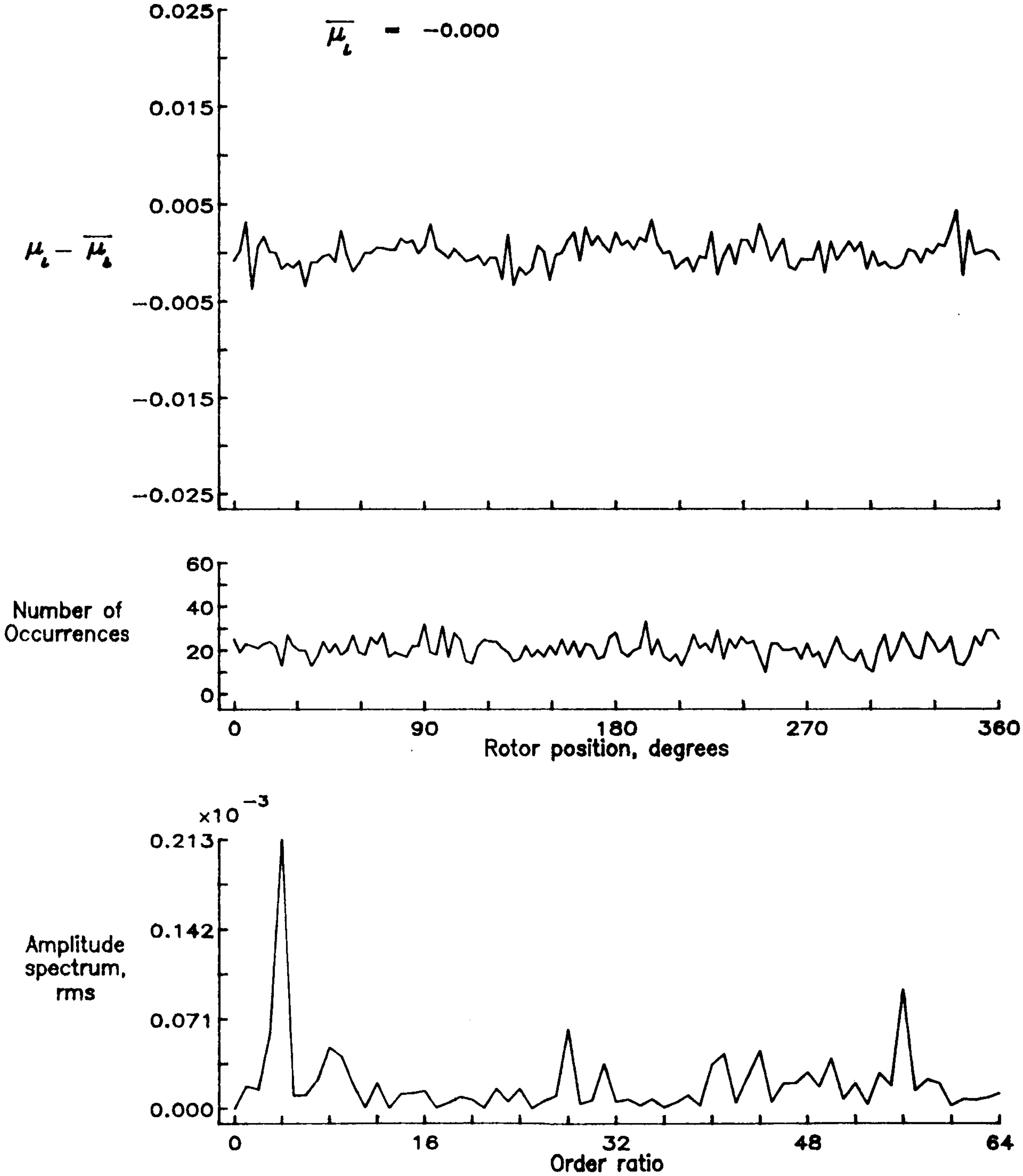
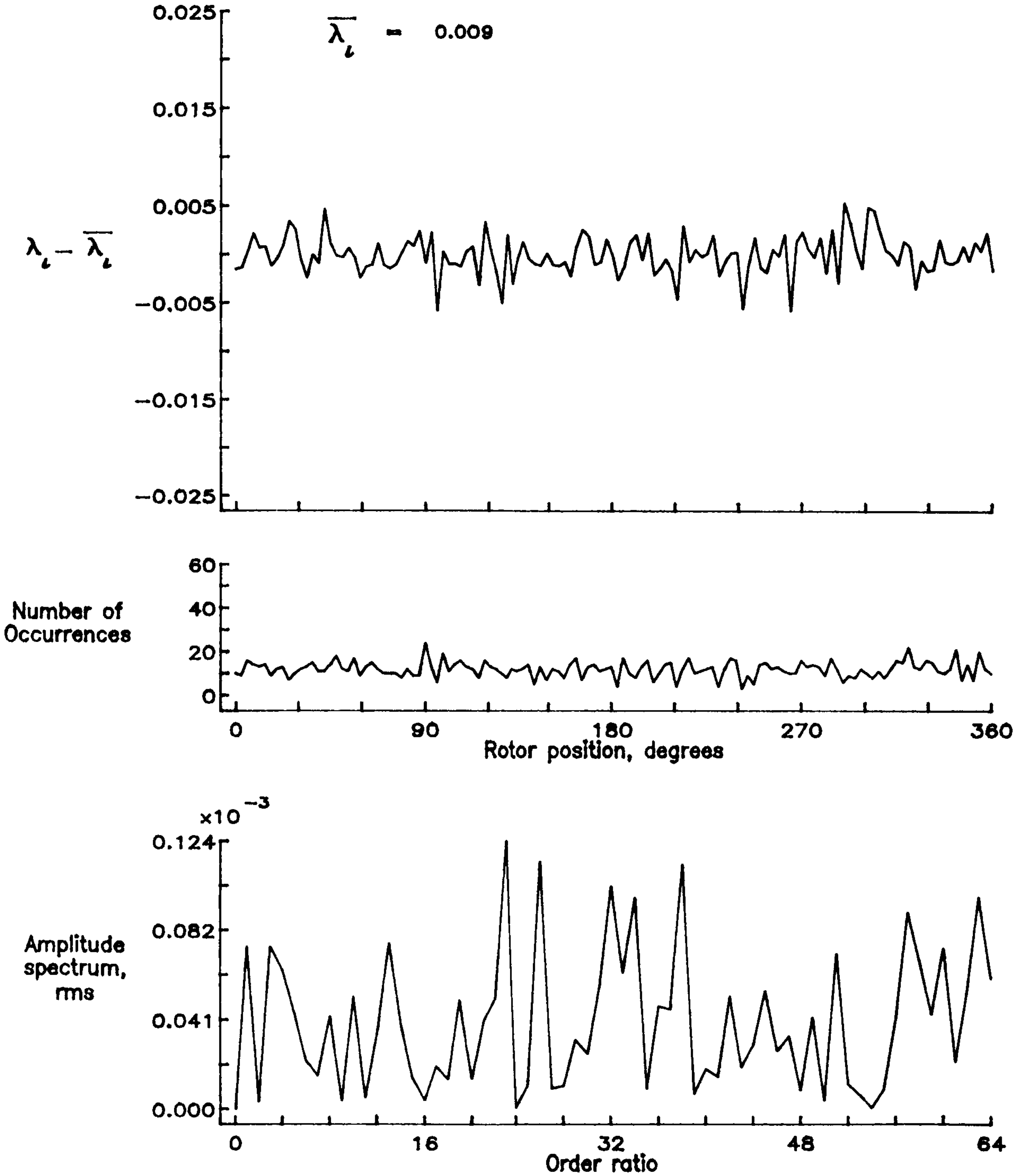


Figure 100.– Induced inflow velocity measured at 150 degrees and r/R of 1.02.



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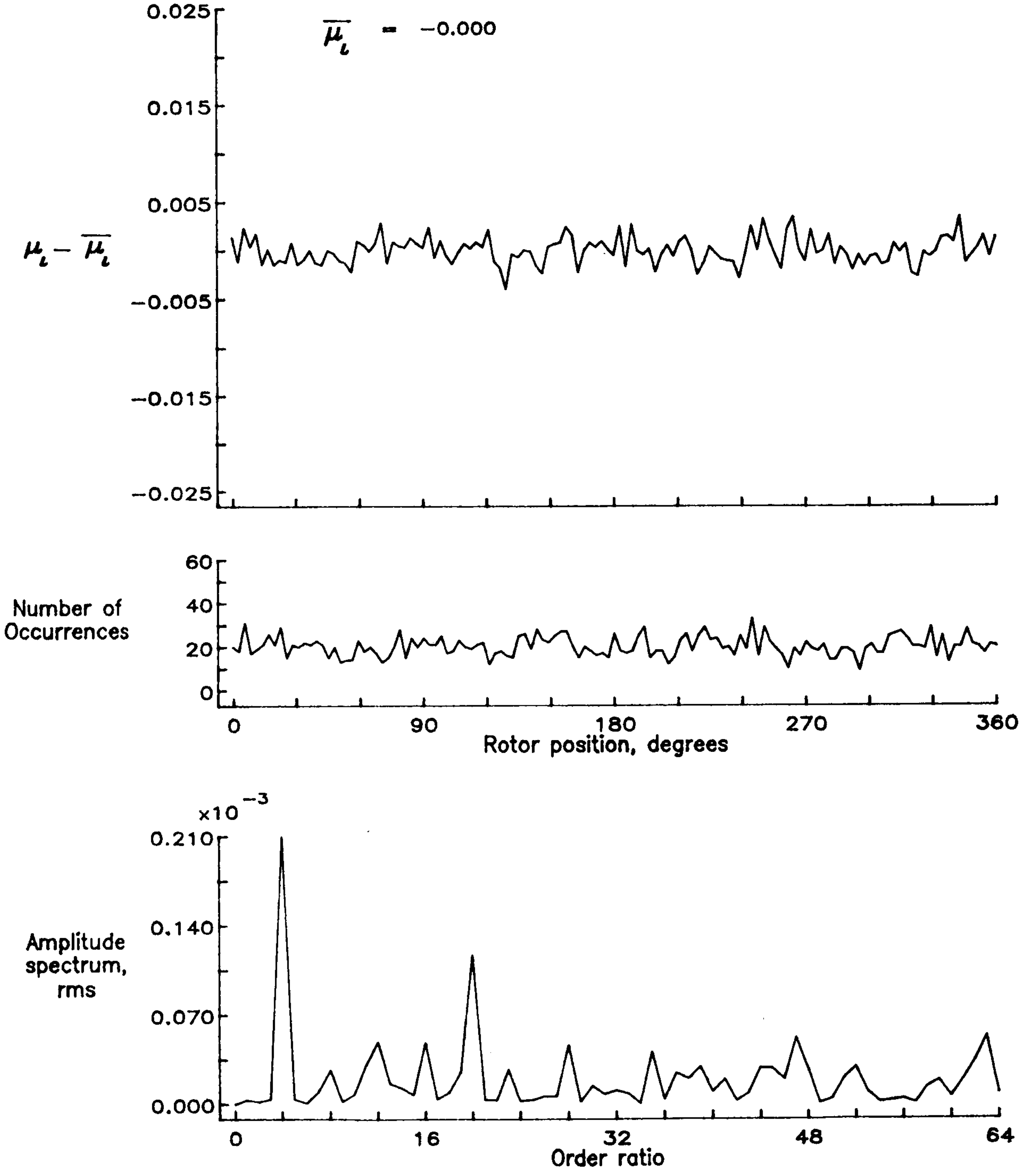
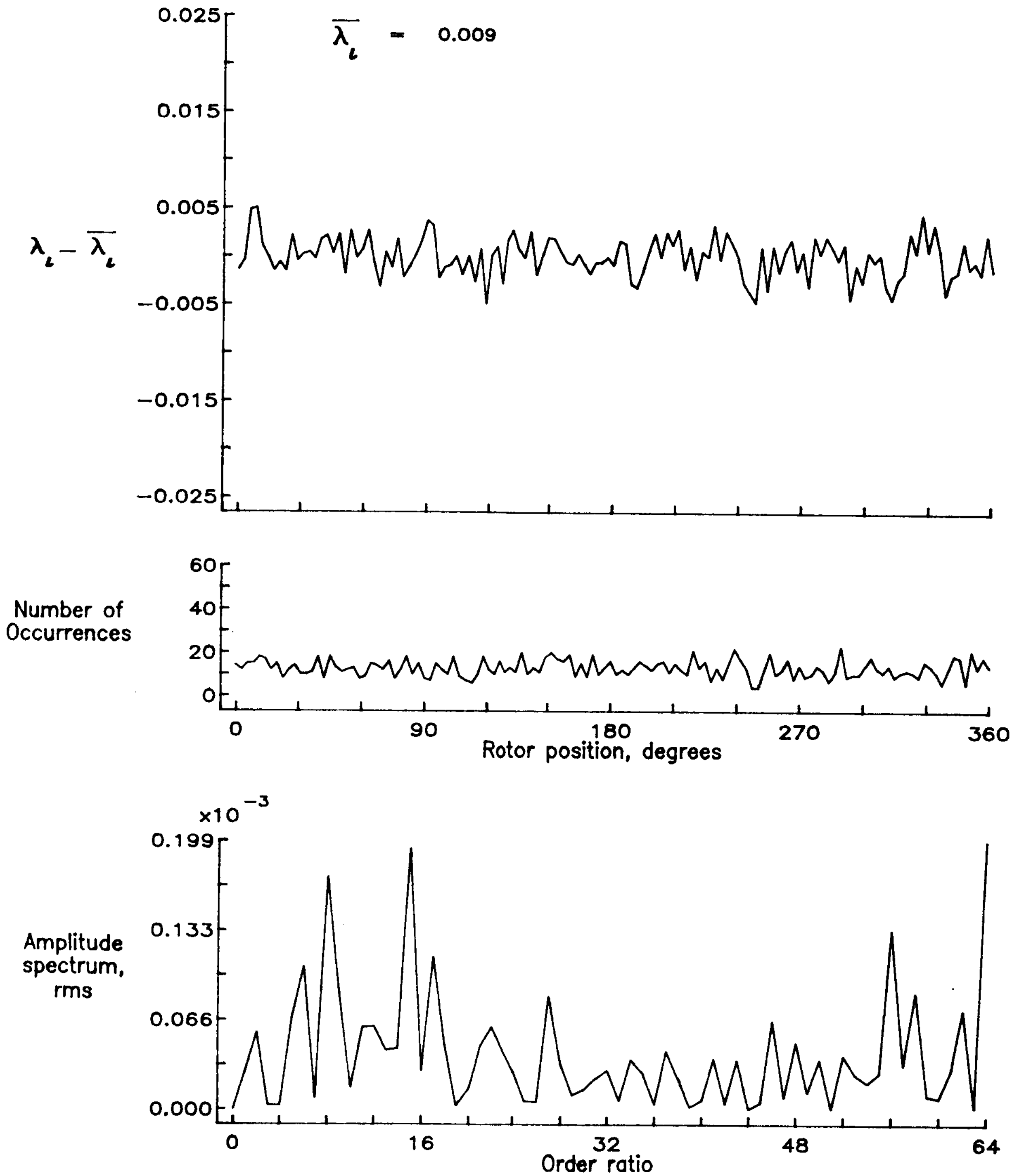


Figure 101.— Induced inflow velocity measured at 150 degrees and r/R of 1.04.



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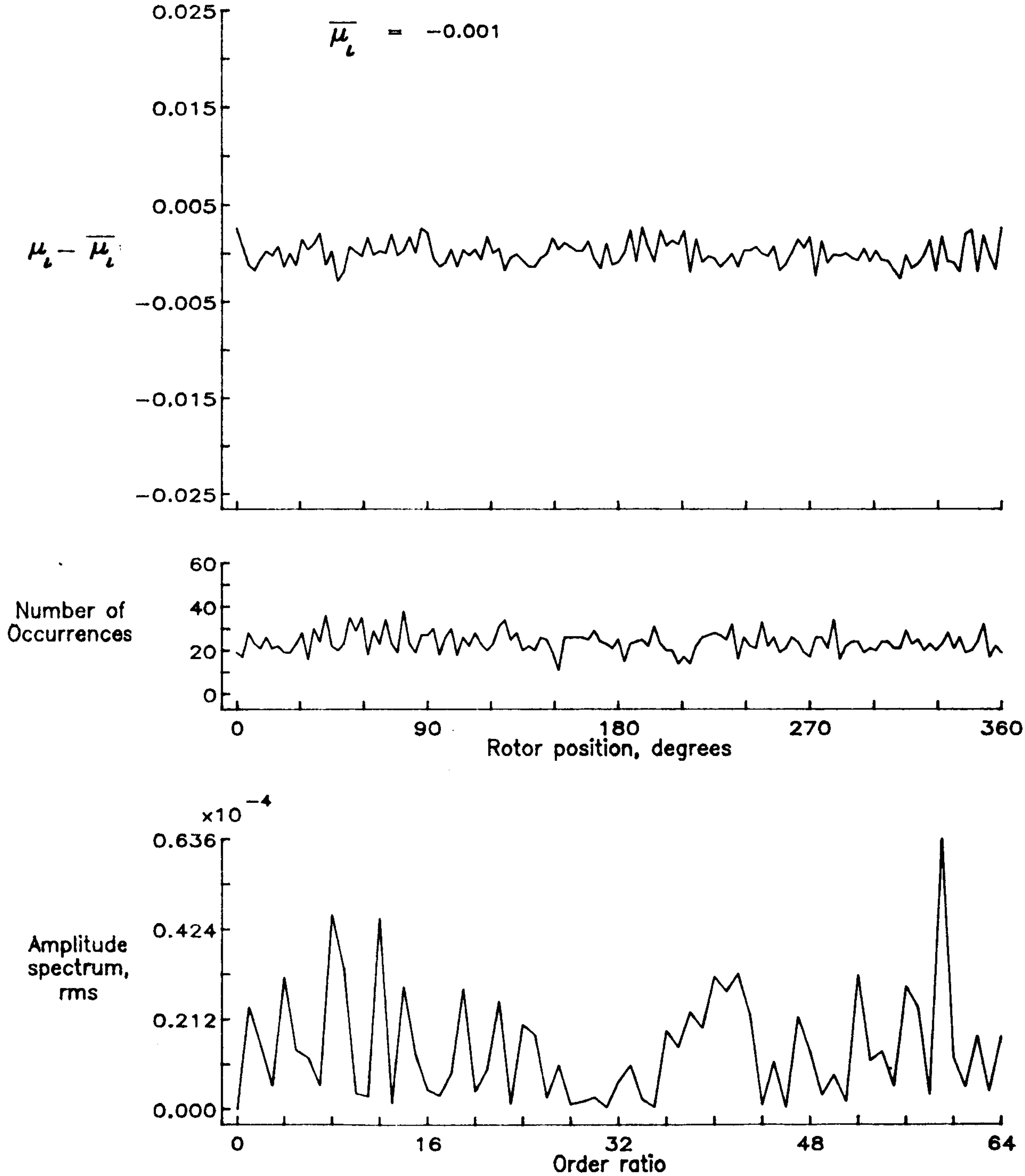
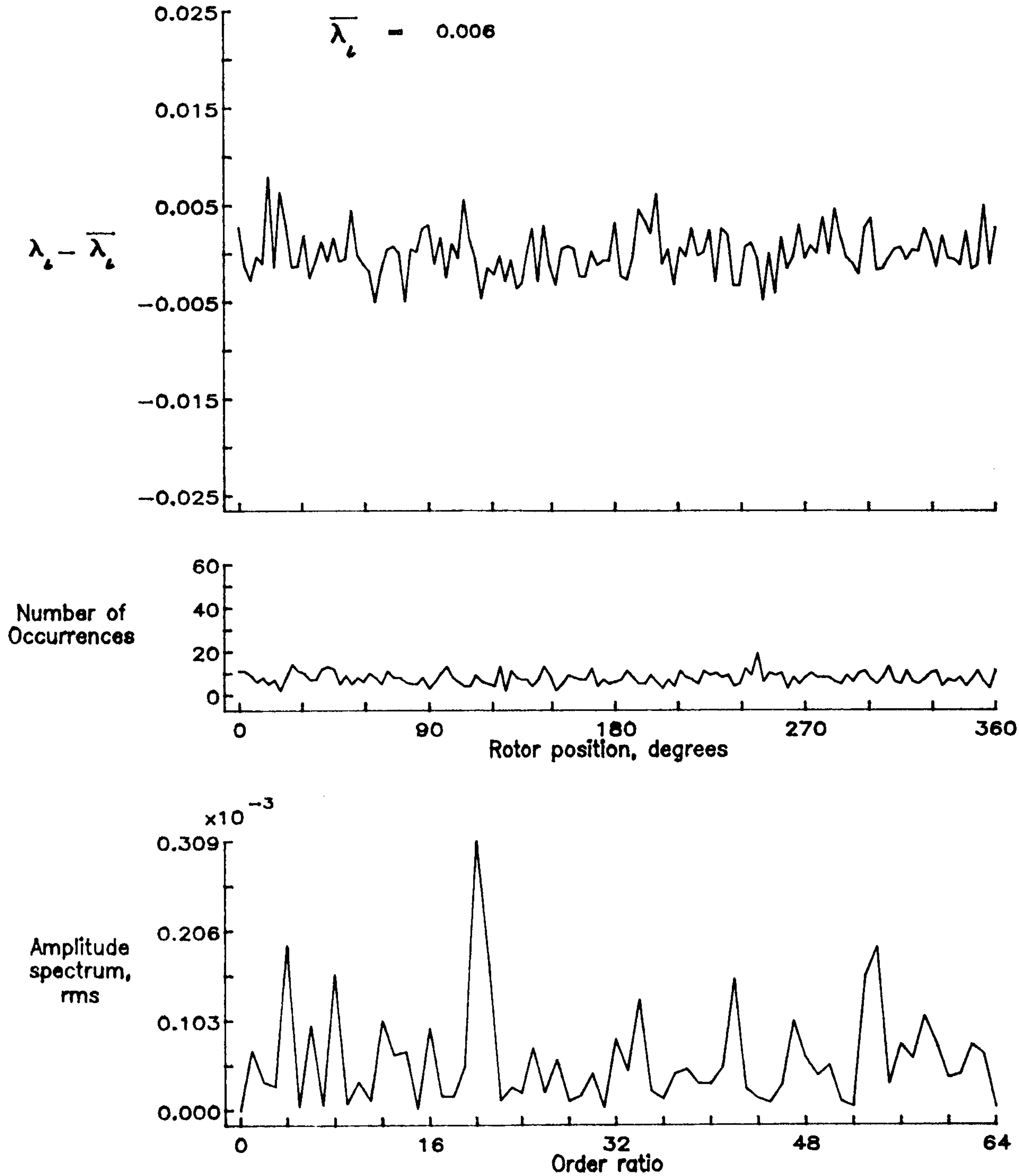


Figure 102.– Induced inflow velocity measured at 150 degrees and r/R of 1.10.



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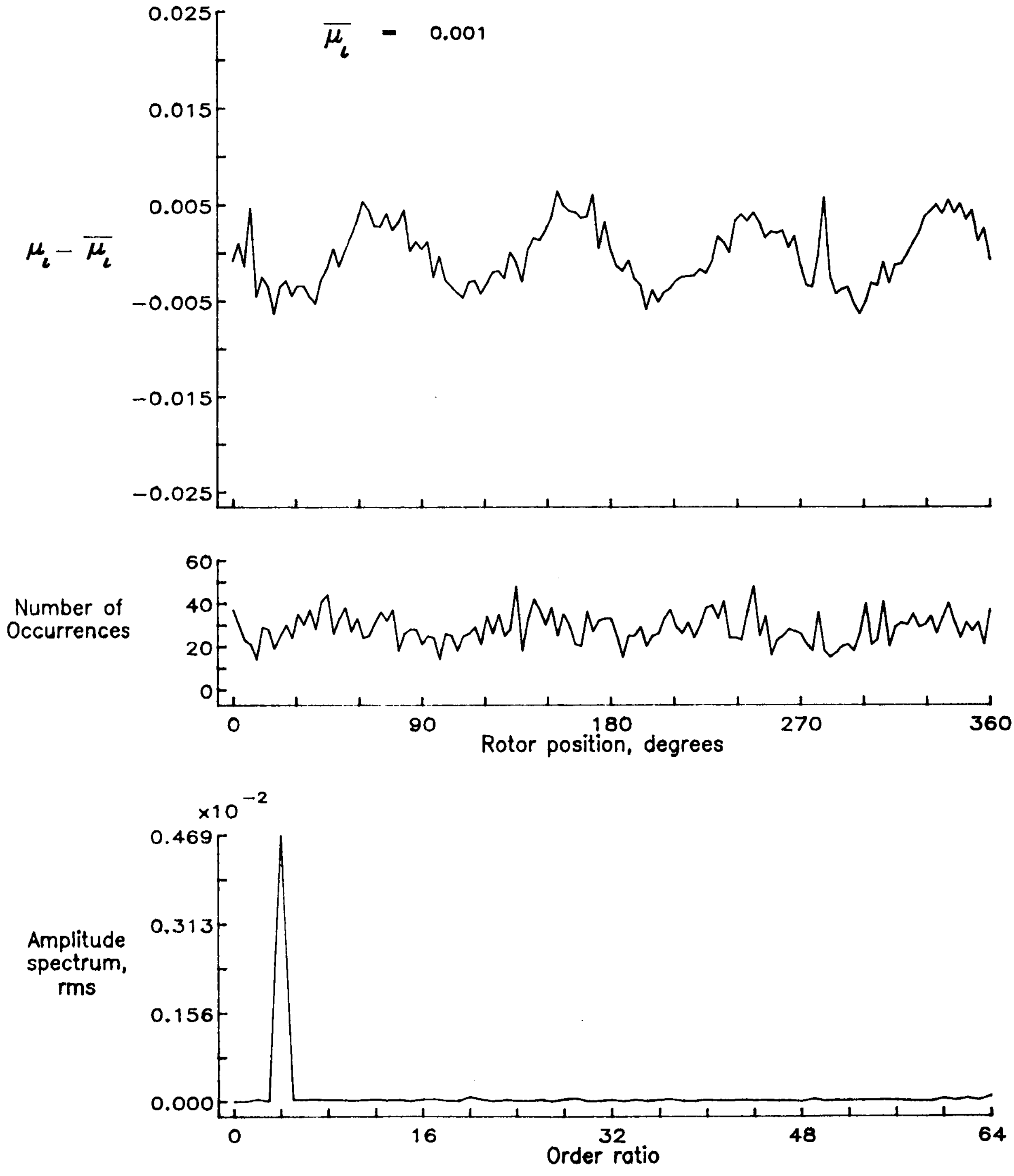
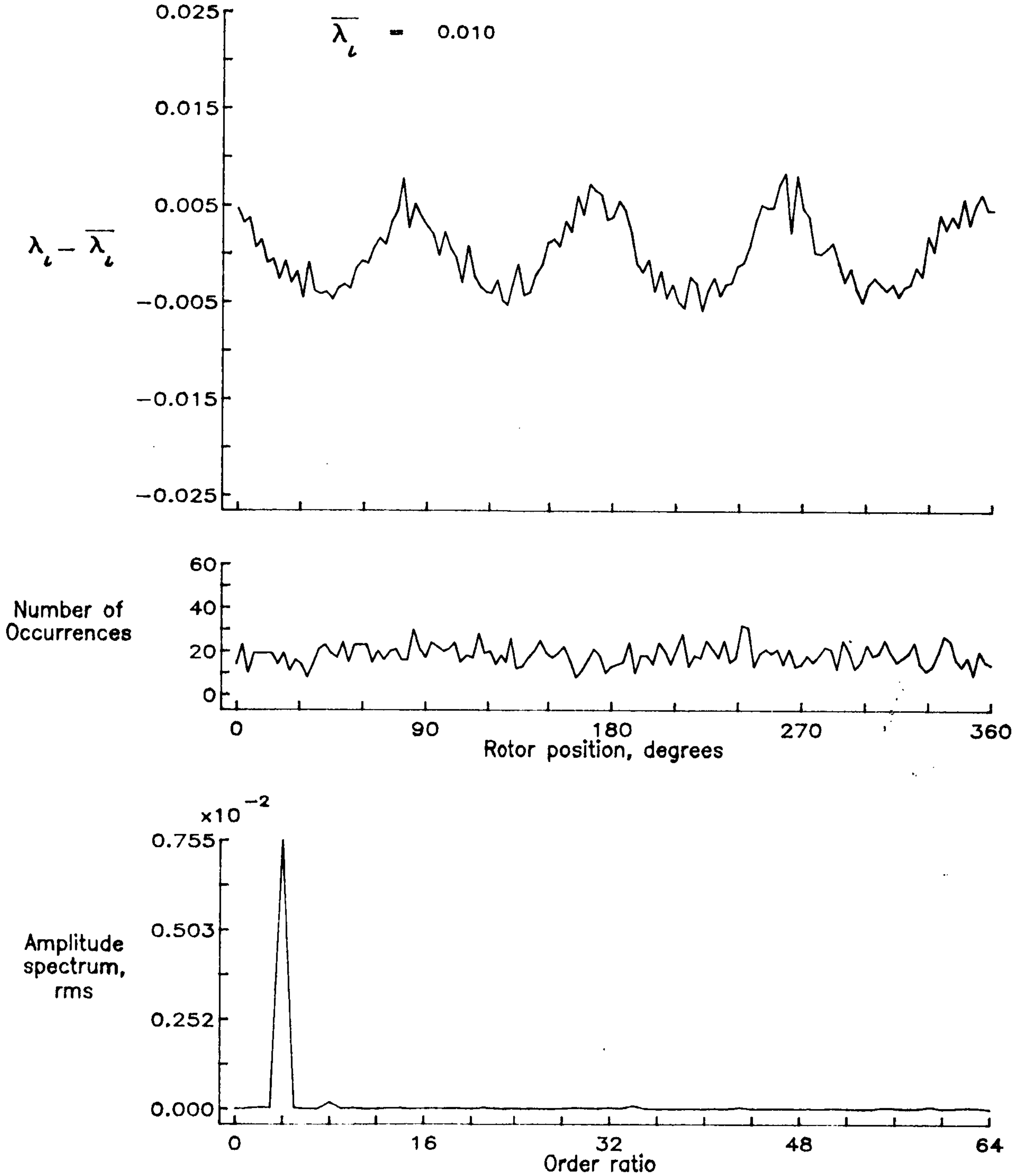


Figure 103.– Induced inflow velocity measured at 180 degrees and r/R of 0.20.



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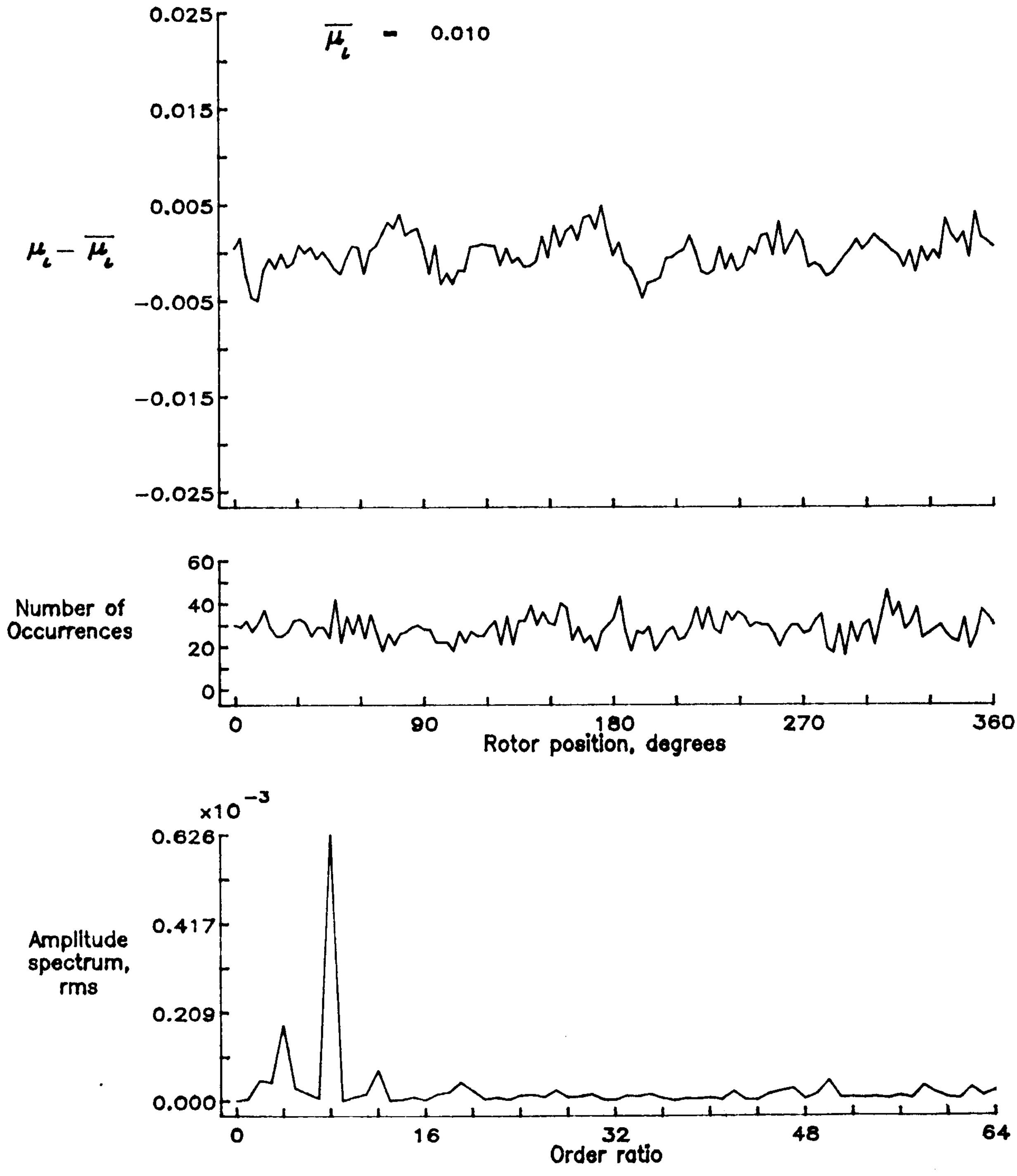
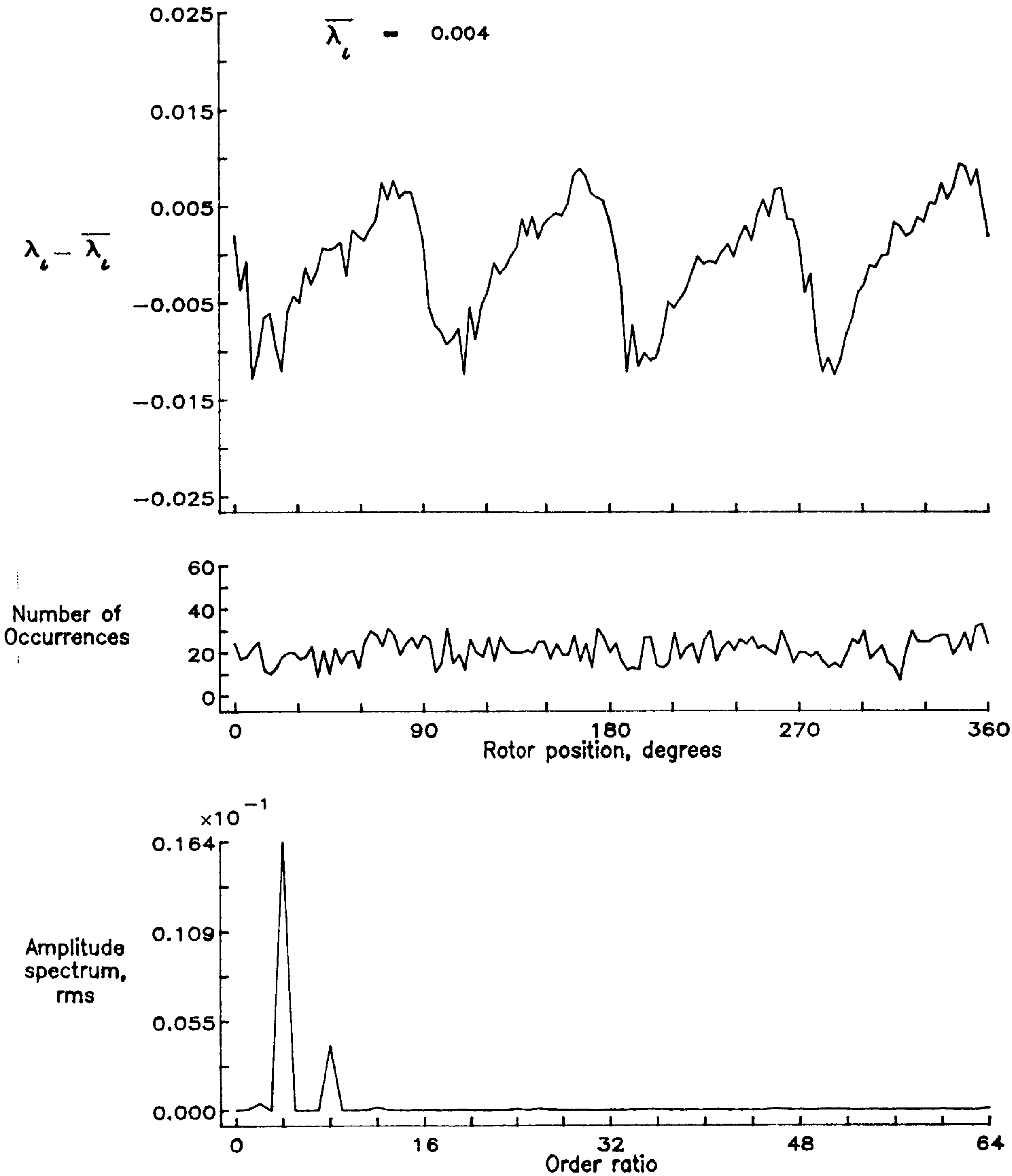


Figure 104.– Induced inflow velocity measured at 180 degrees and r/R of 0.40.



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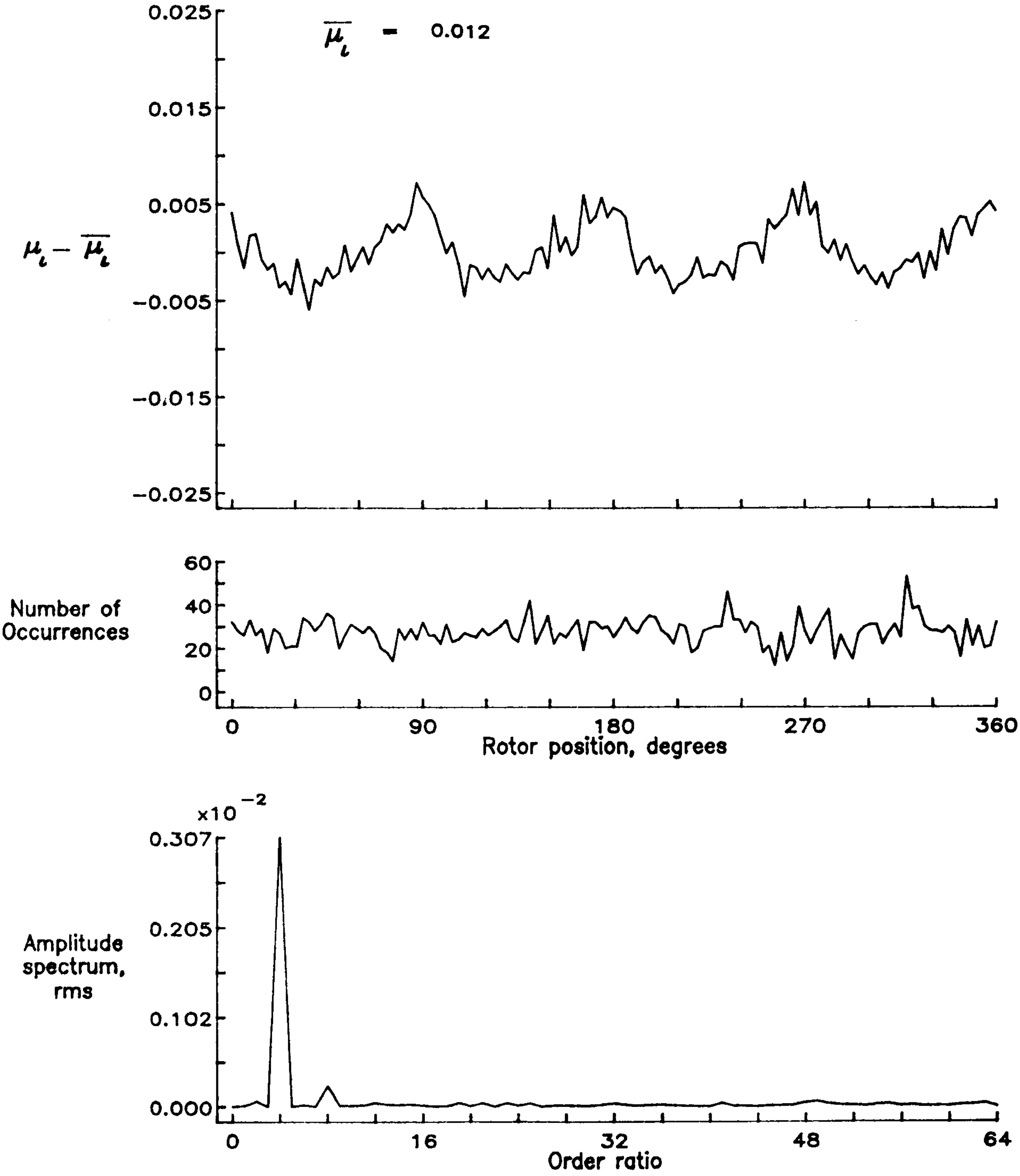
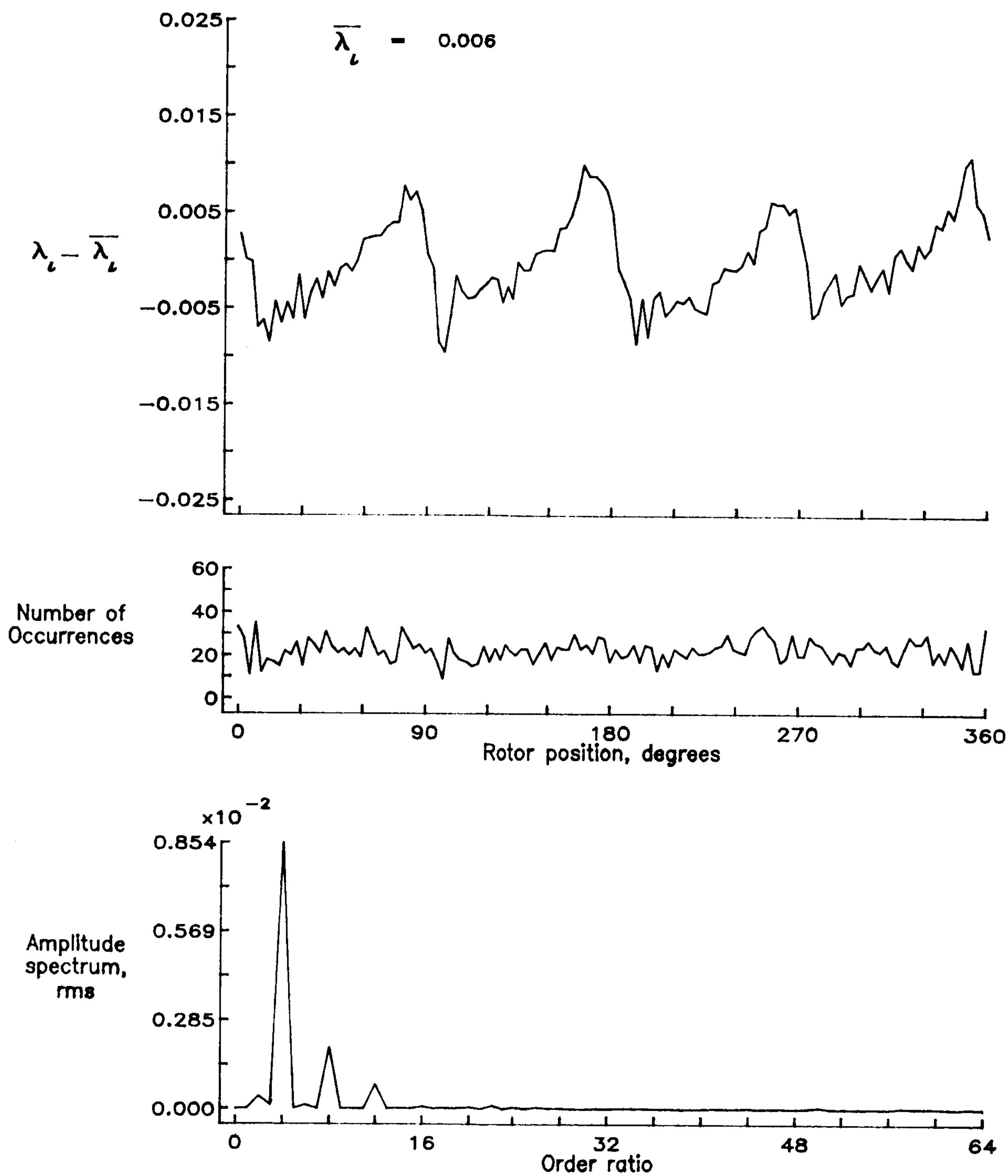


Figure 105.– Induced inflow velocity measured at 180 degrees and r/R of 0.50.



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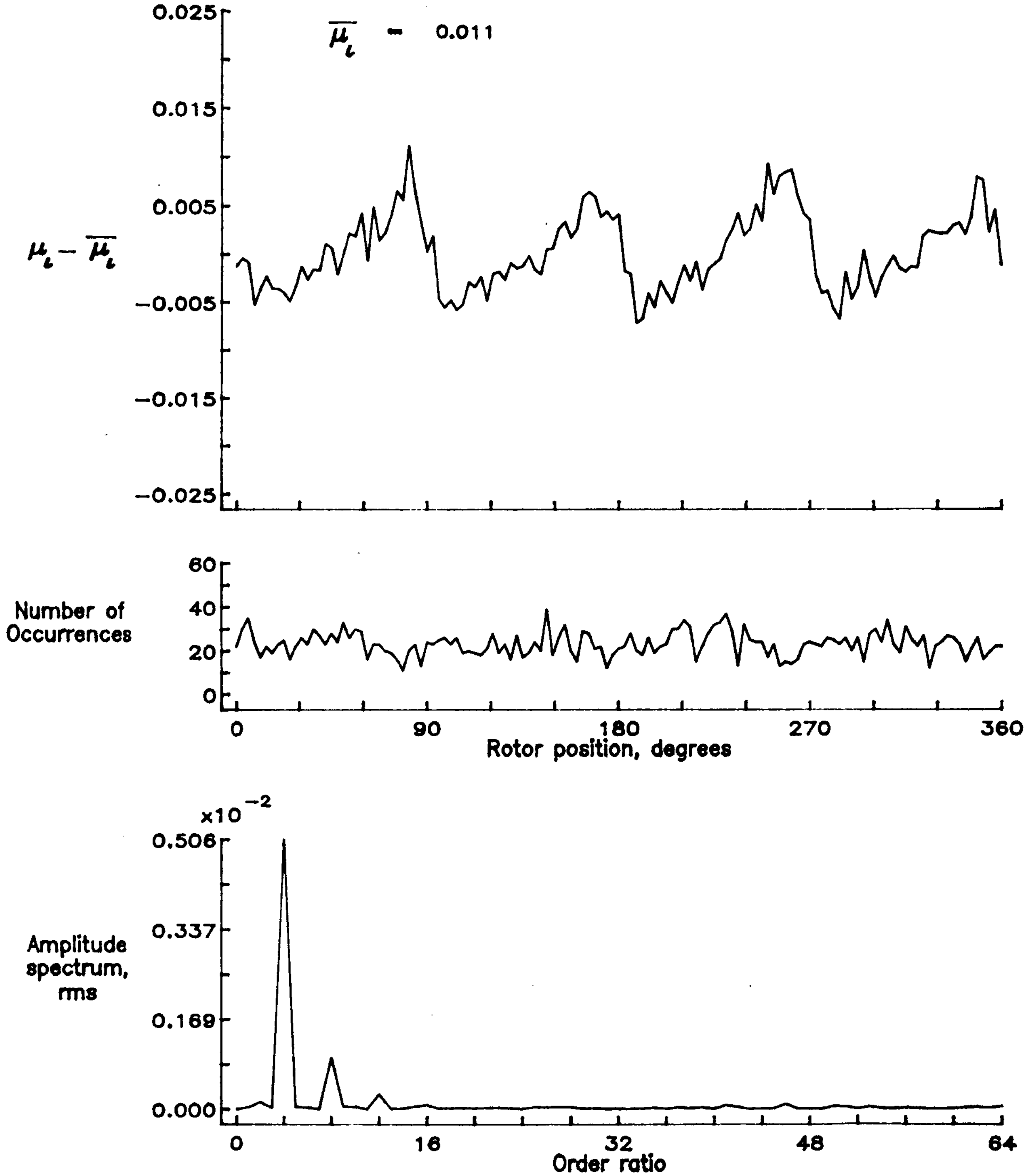
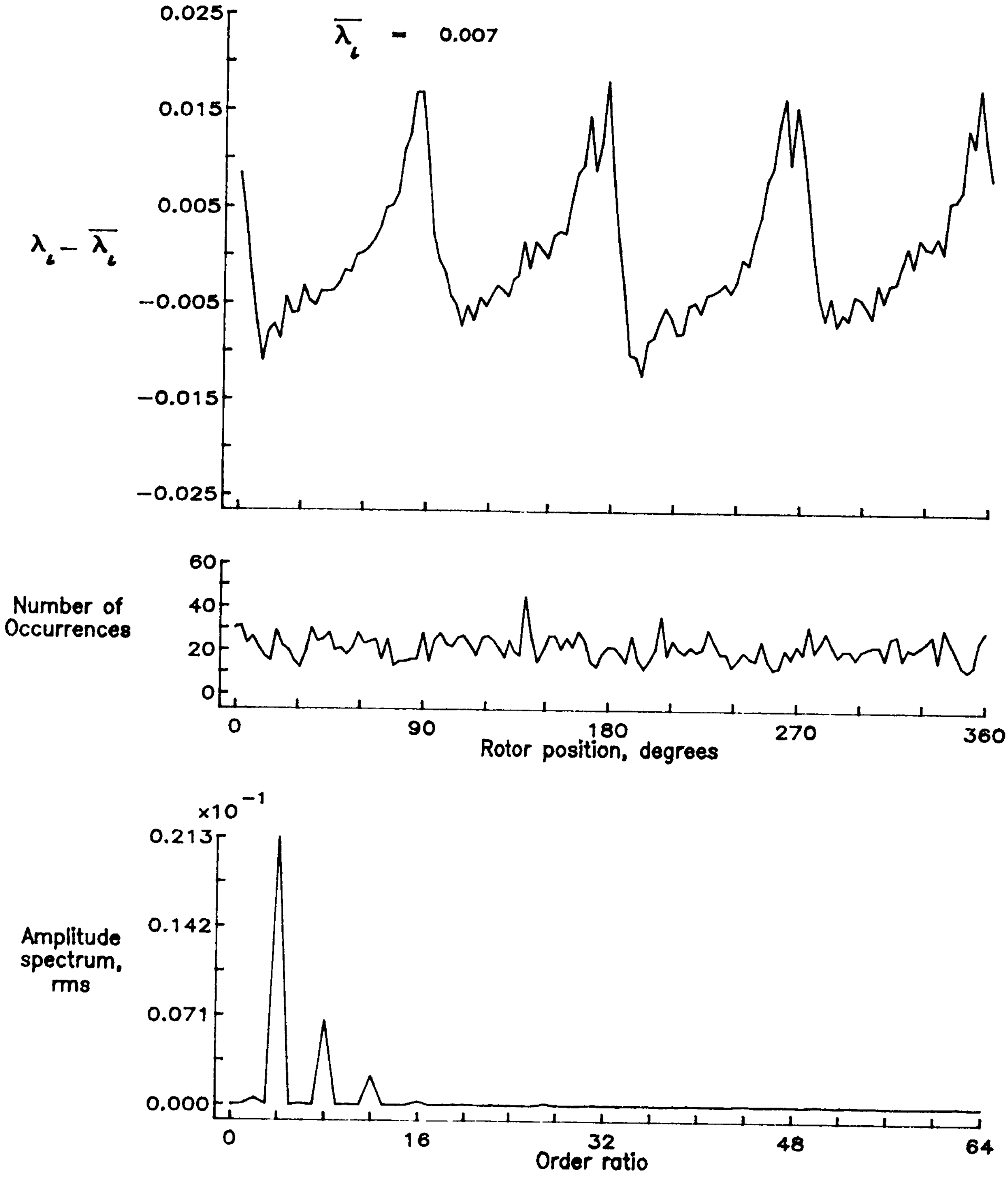


Figure 106.— Induced inflow velocity measured at 180 degrees and r/R of 0.60.



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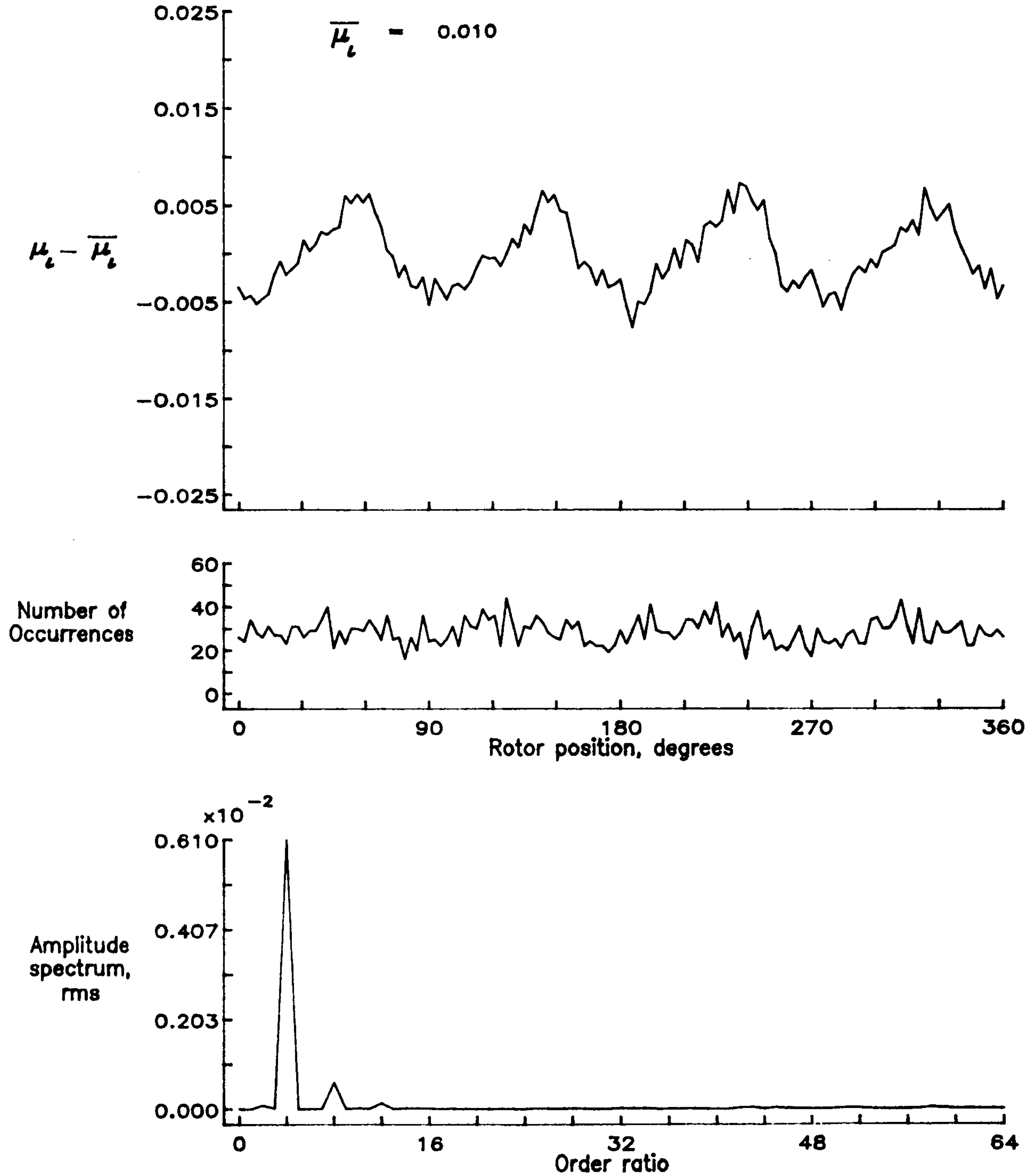
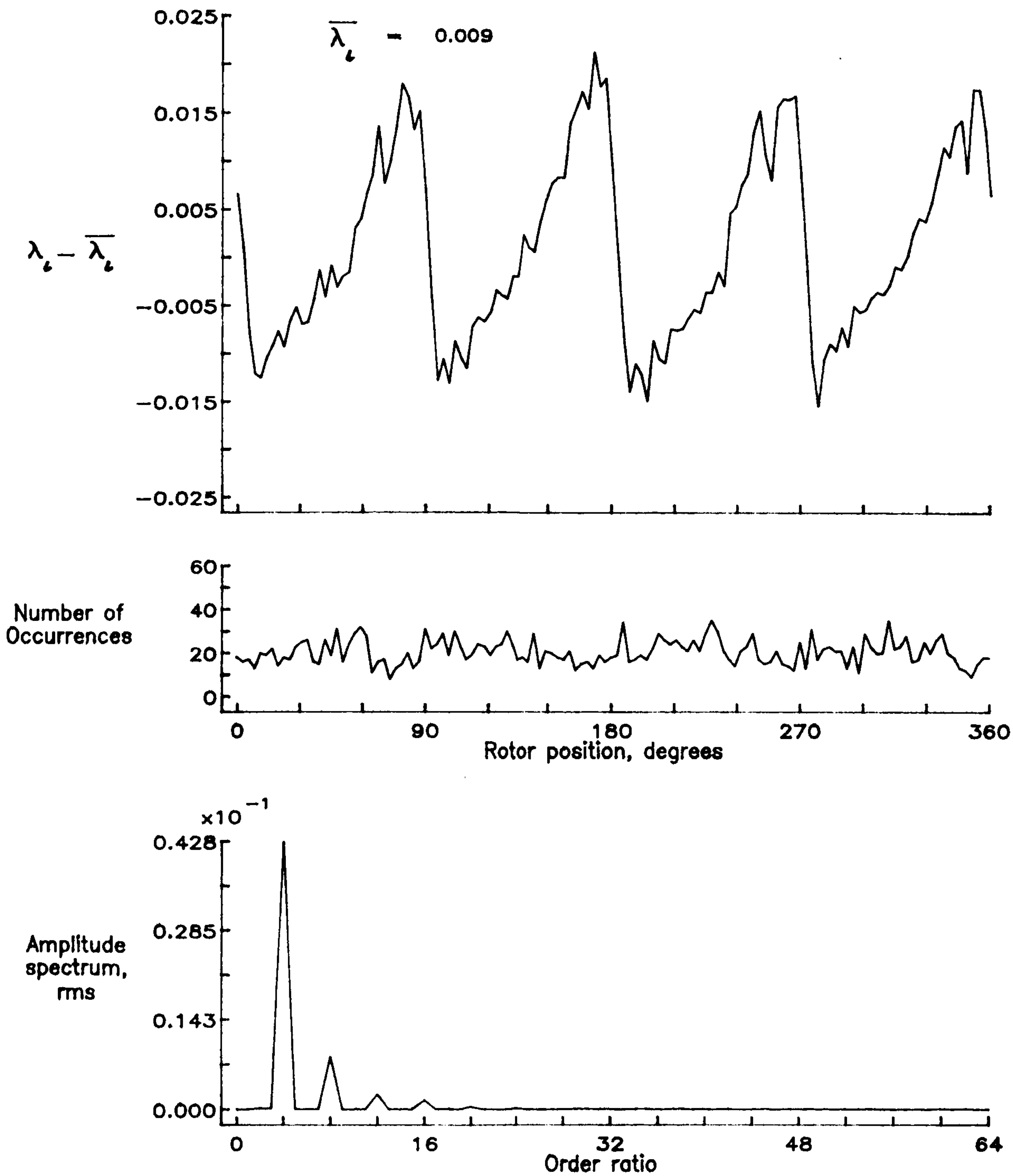


Figure 107.– Induced inflow velocity measured at 180 degrees and r/R of 0.70.



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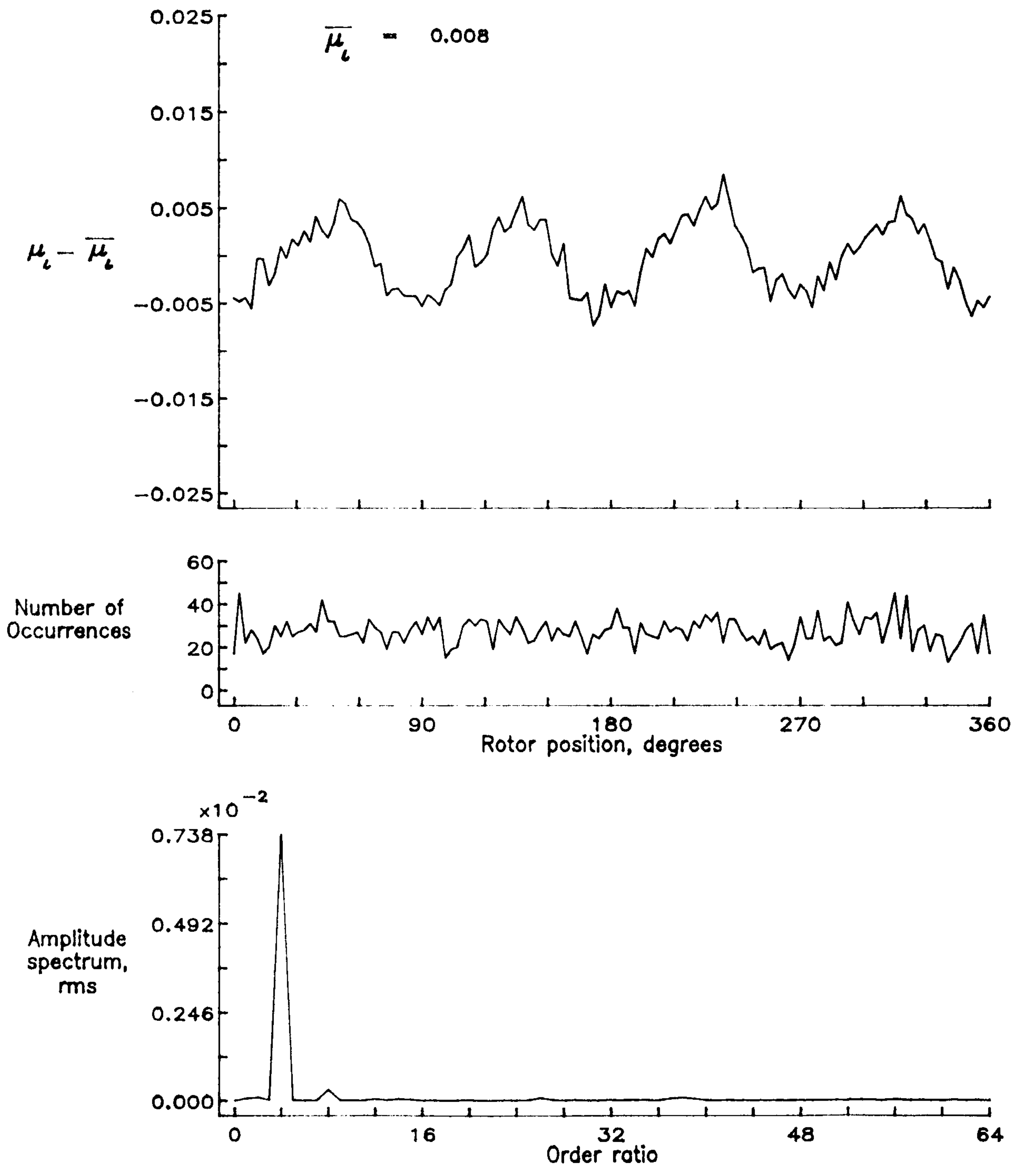
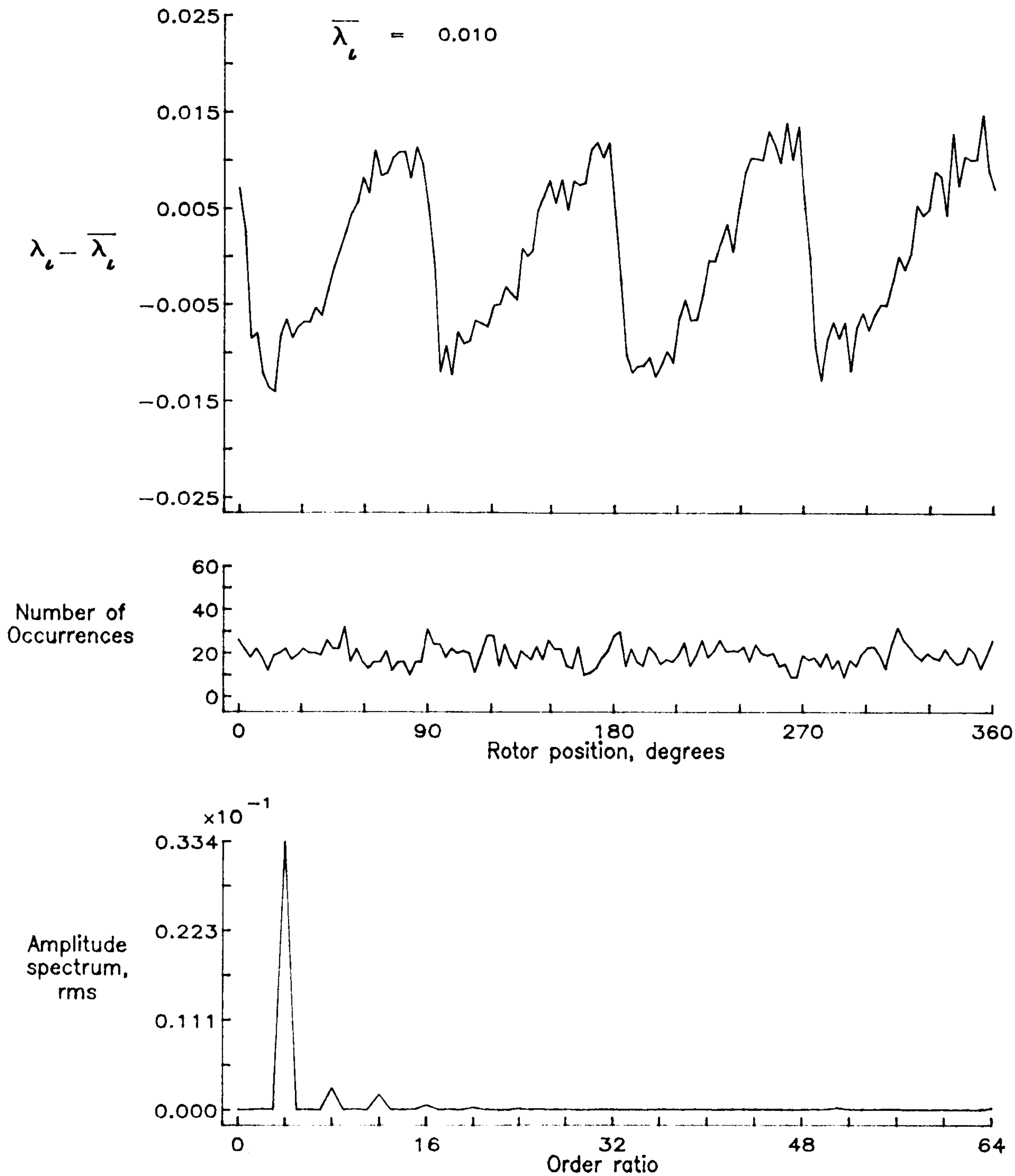


Figure 108.— Induced inflow velocity measured at 180 degrees and r/R of 0.74.



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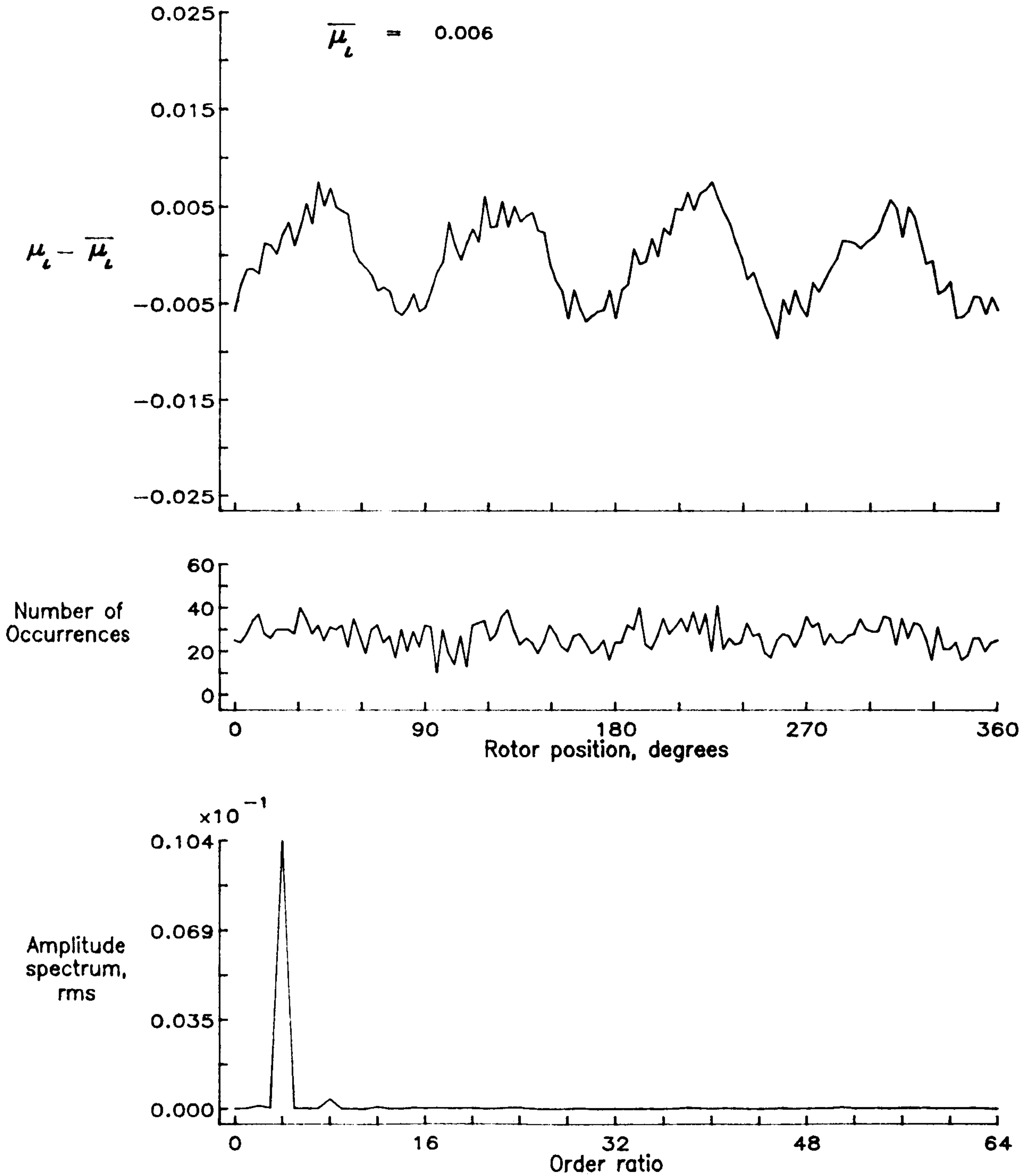
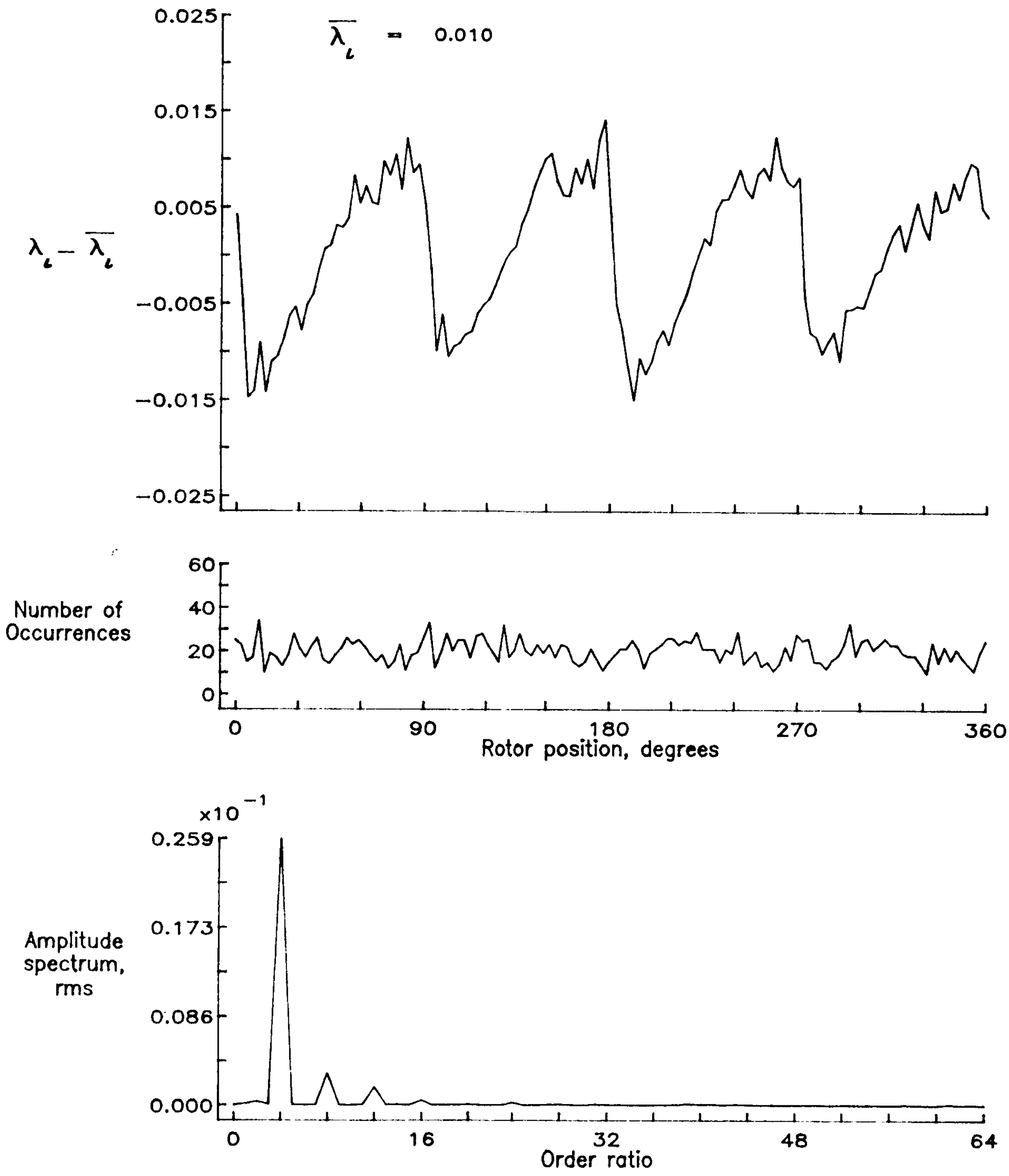


Figure 109.– Induced inflow velocity measured at 180 degrees and r/R of 0.78.



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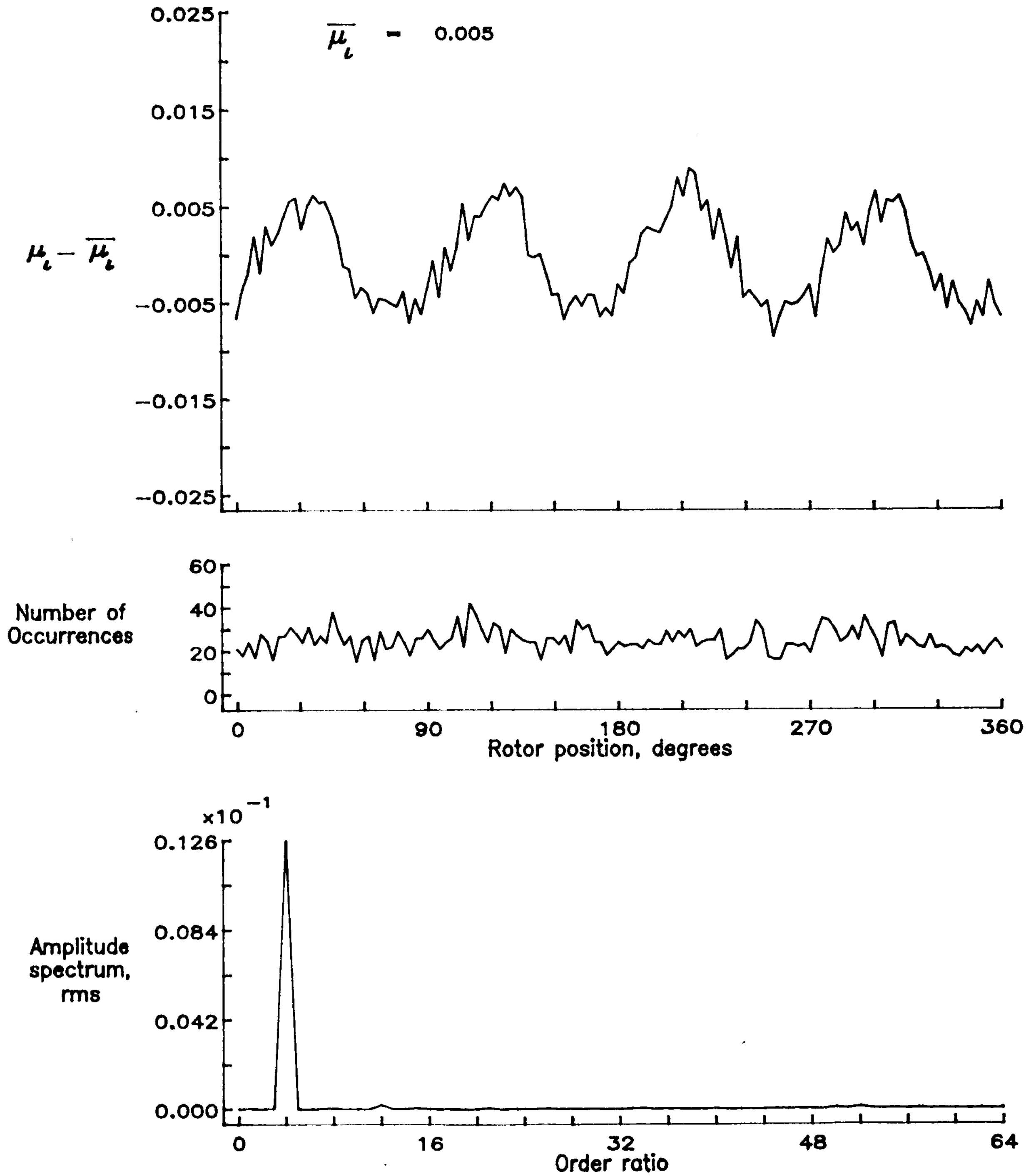
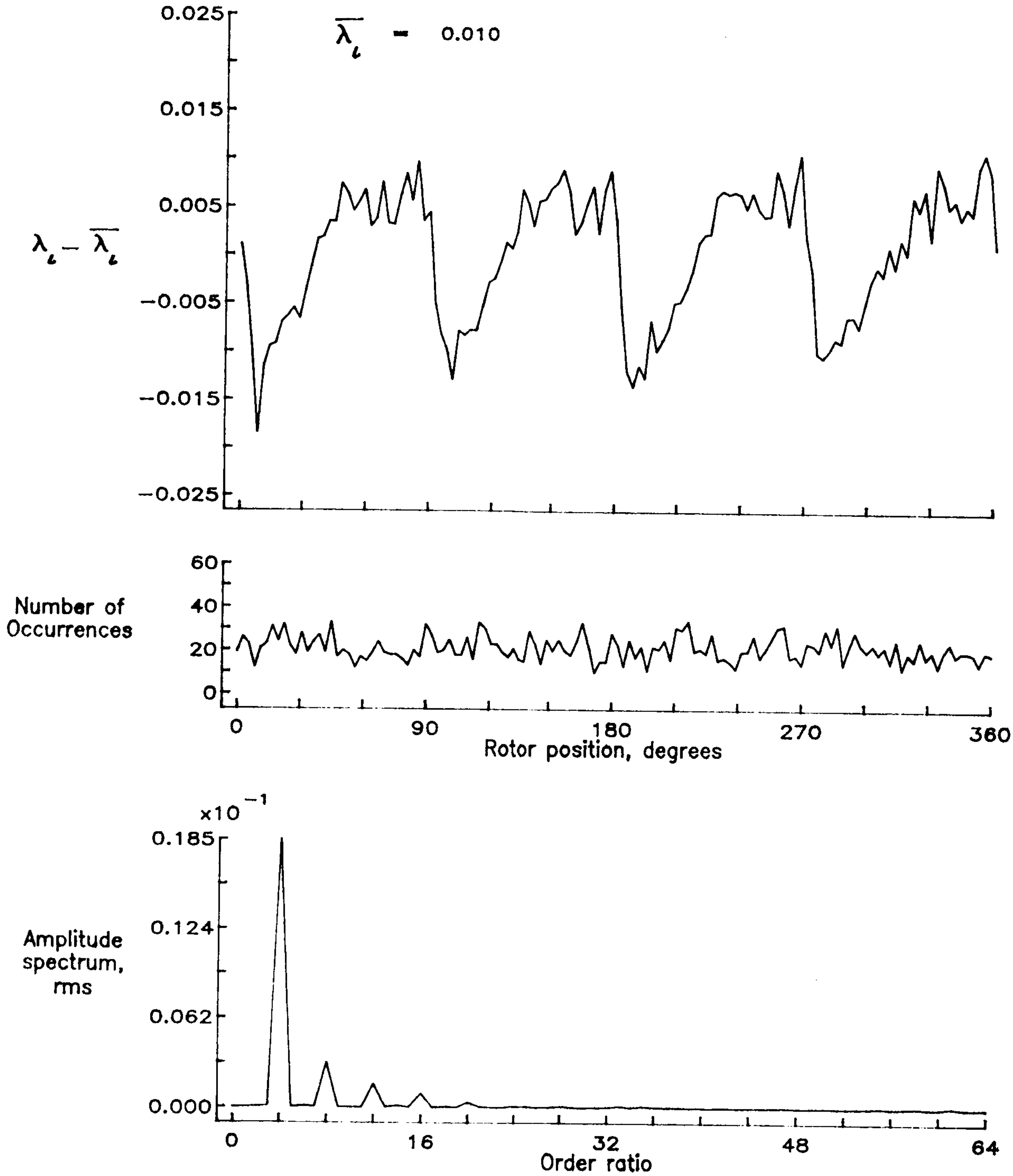


Figure 110.– Induced inflow velocity measured at 180 degrees and r/R of 0.82.



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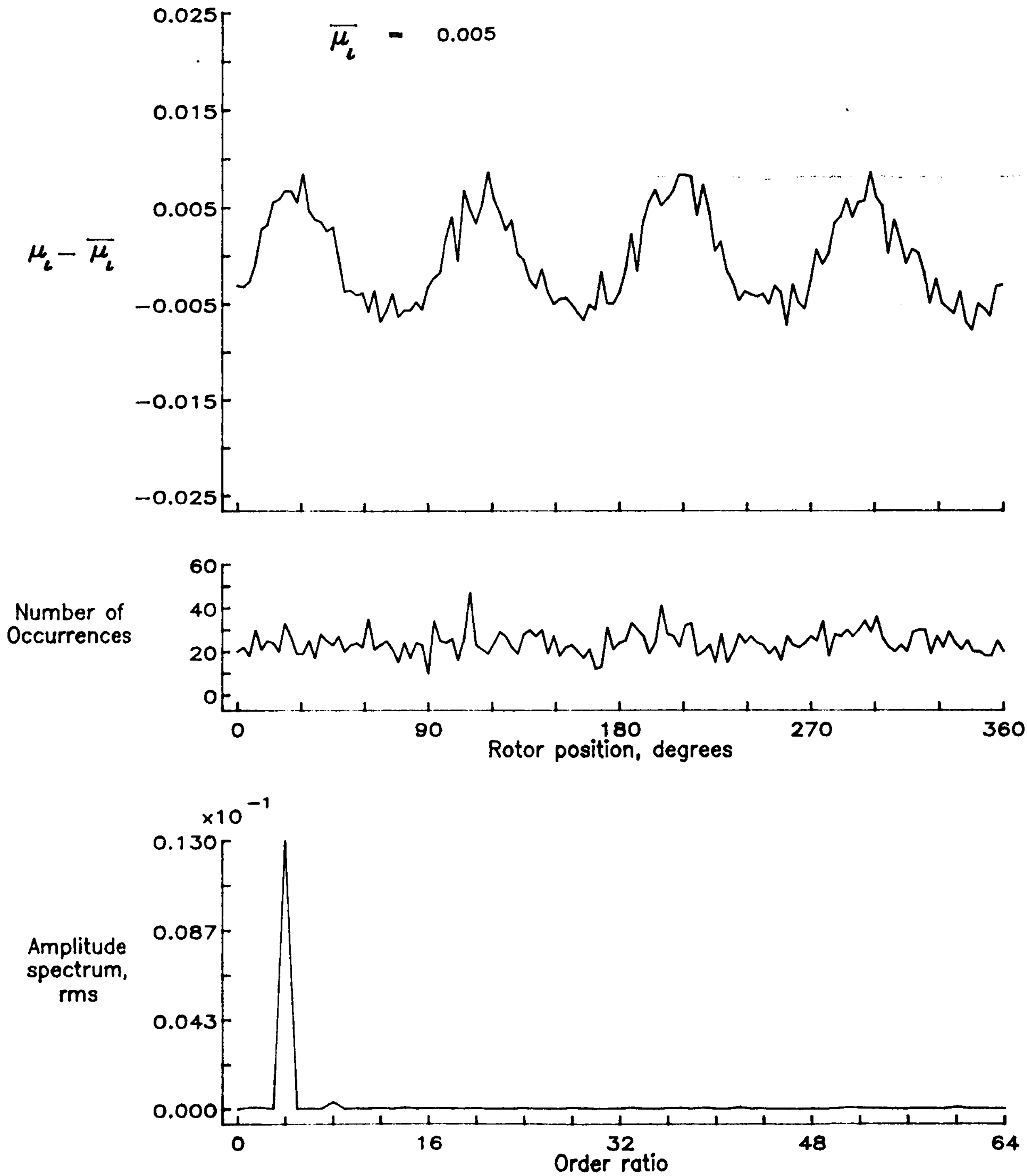
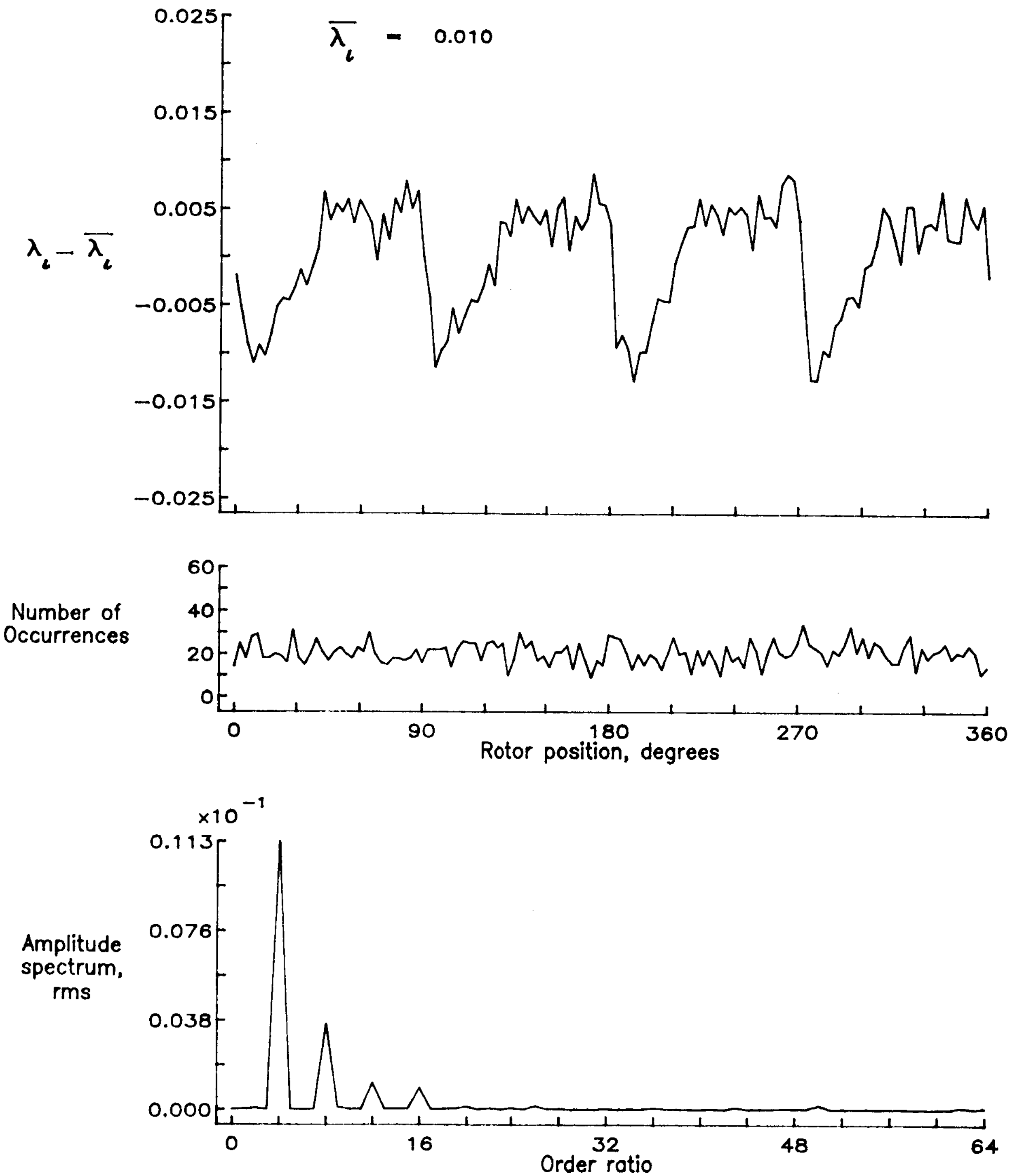


Figure 111.– Induced inflow velocity measured at 180 degrees and r/R of 0.86.



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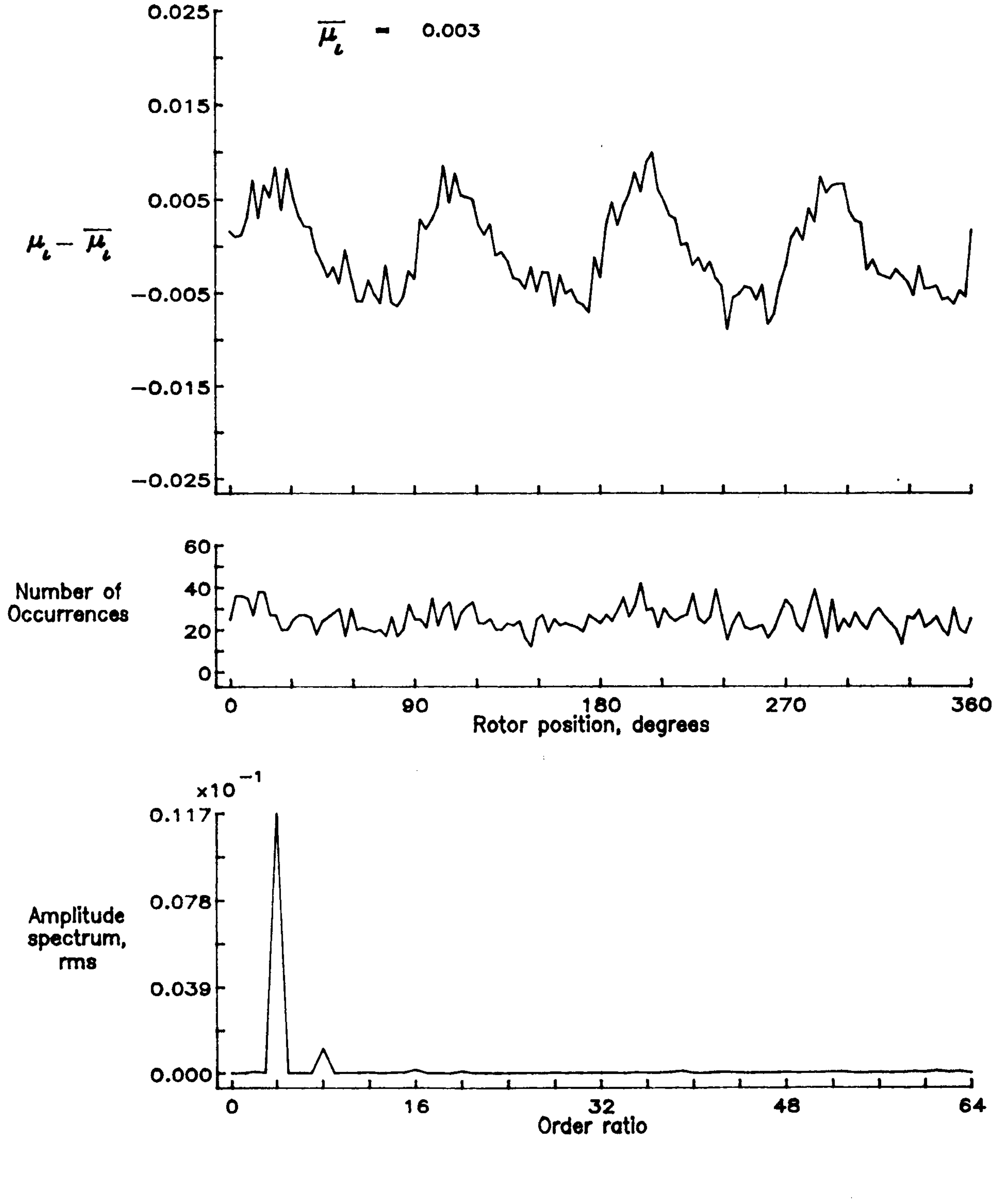
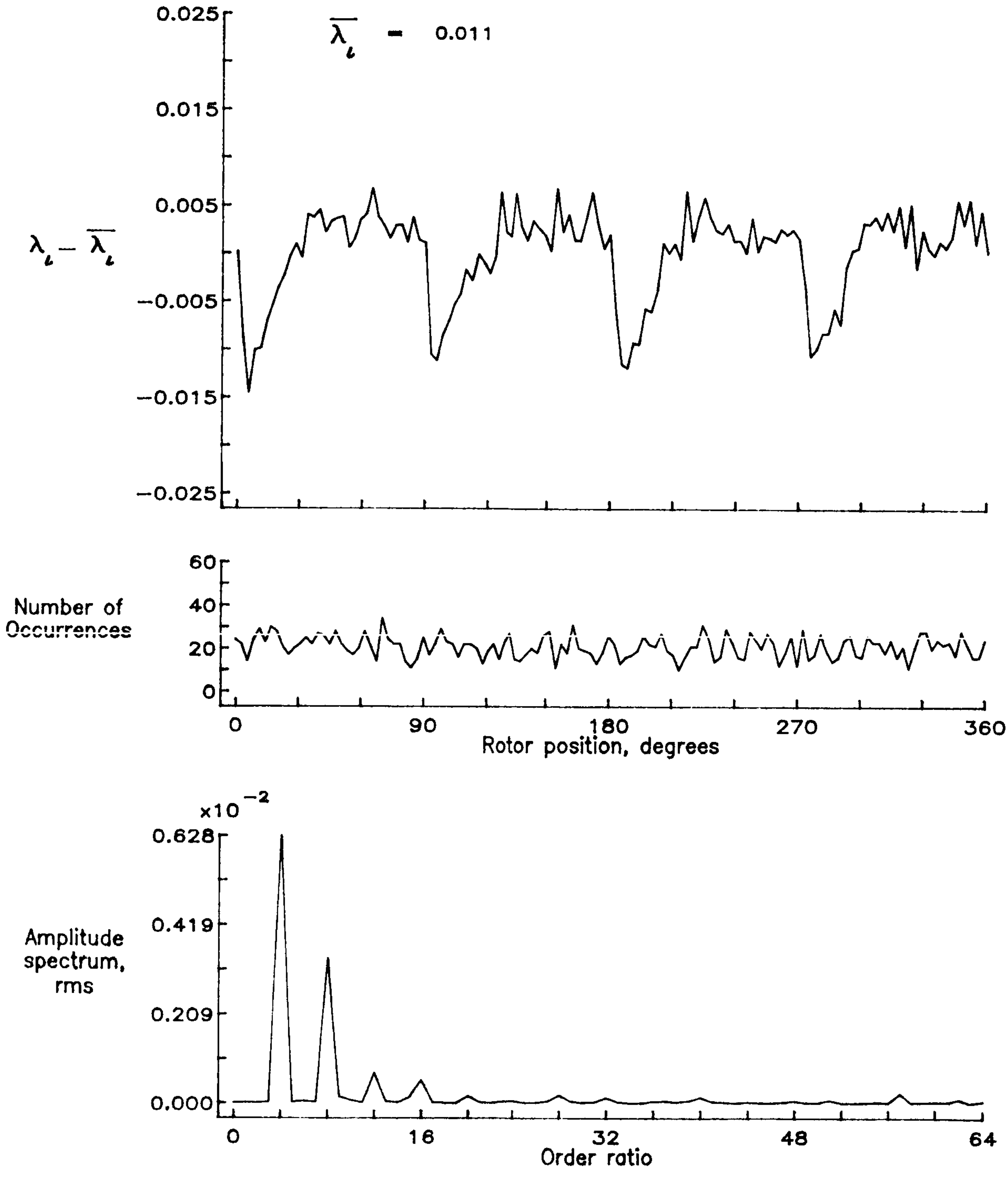


Figure 112.— Induced inflow velocity measured at 180 degrees and r/R of 0.90.



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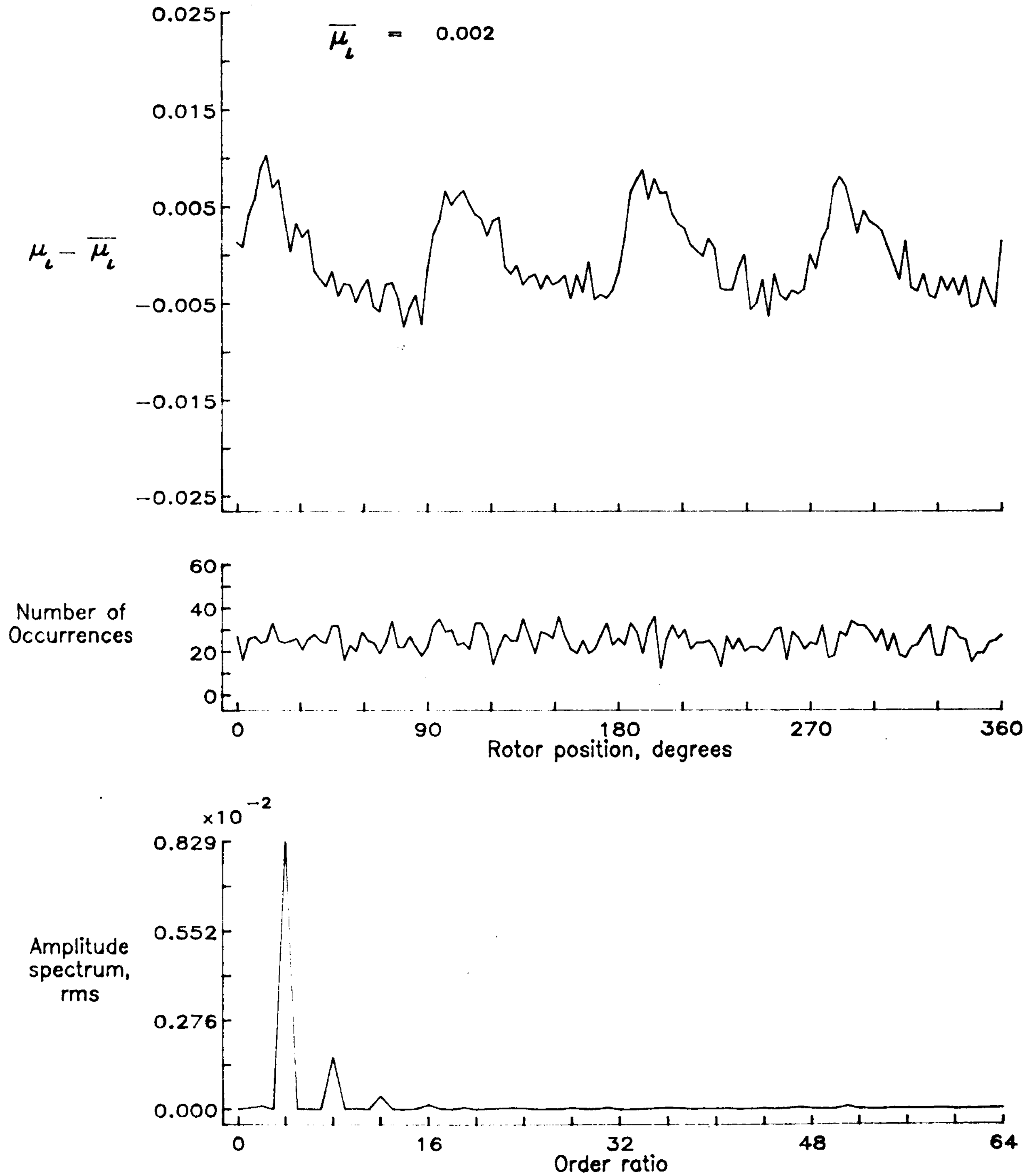
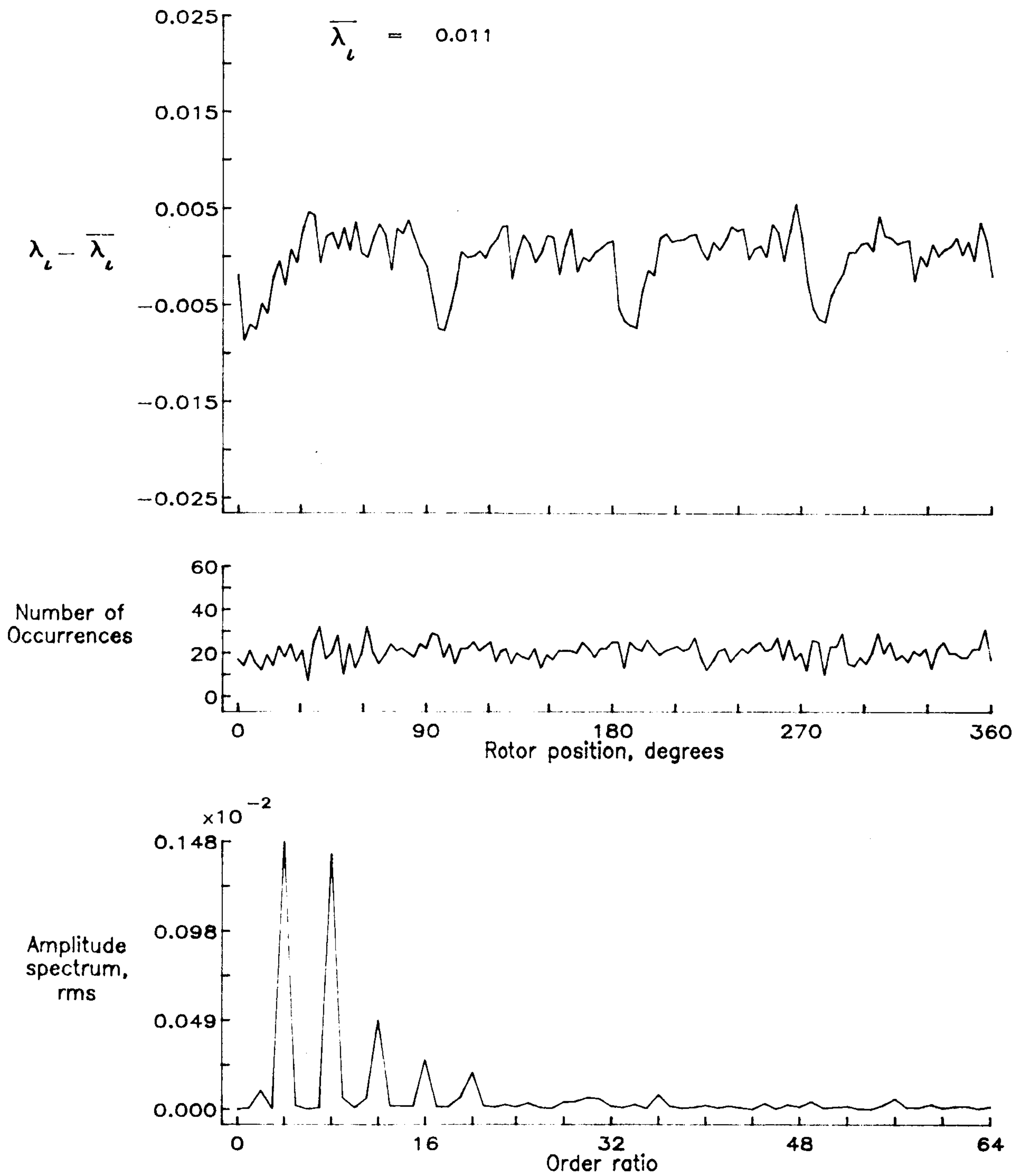


Figure 113.– Induced inflow velocity measured at 180 degrees and r/R of 0.94.



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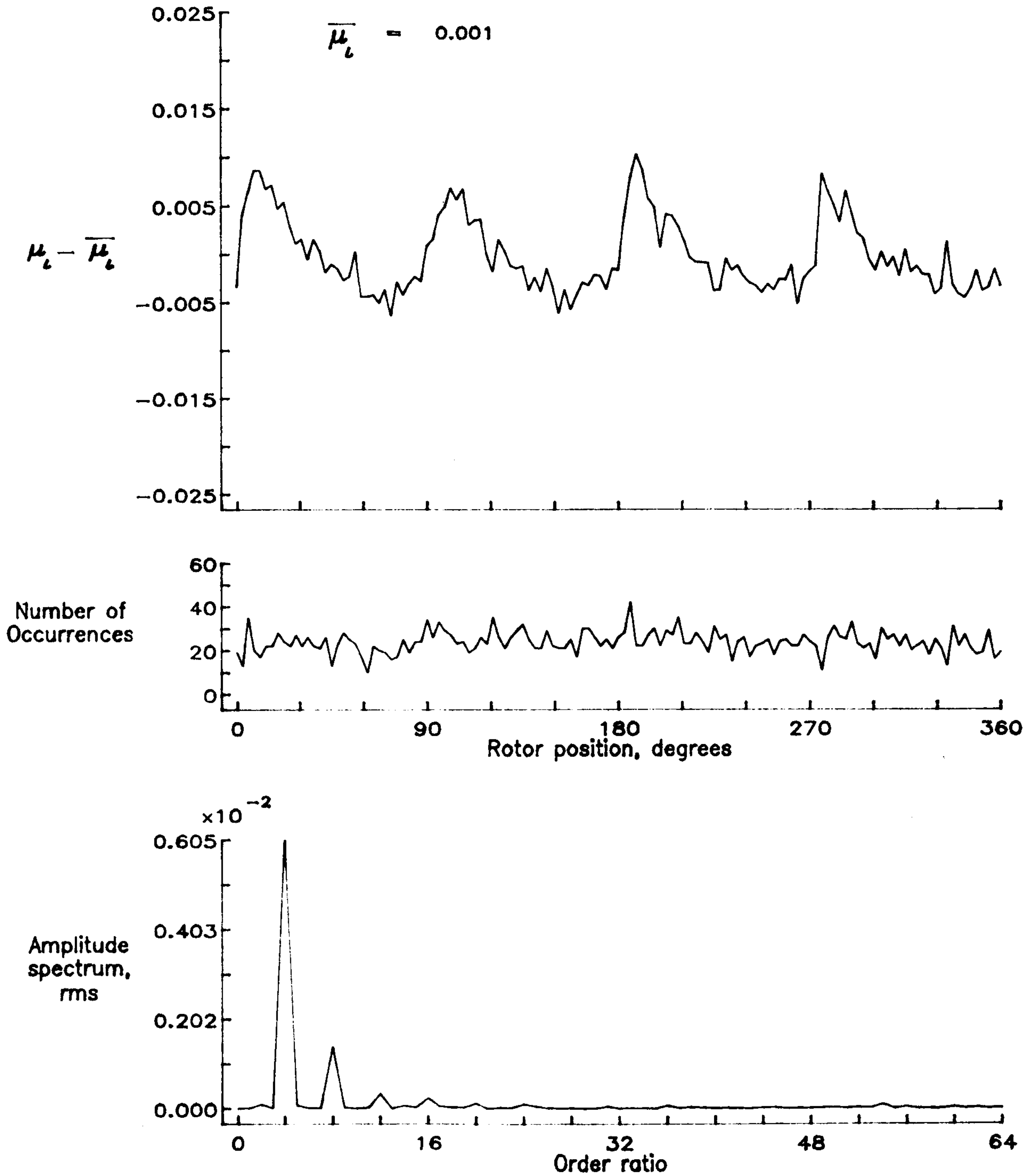
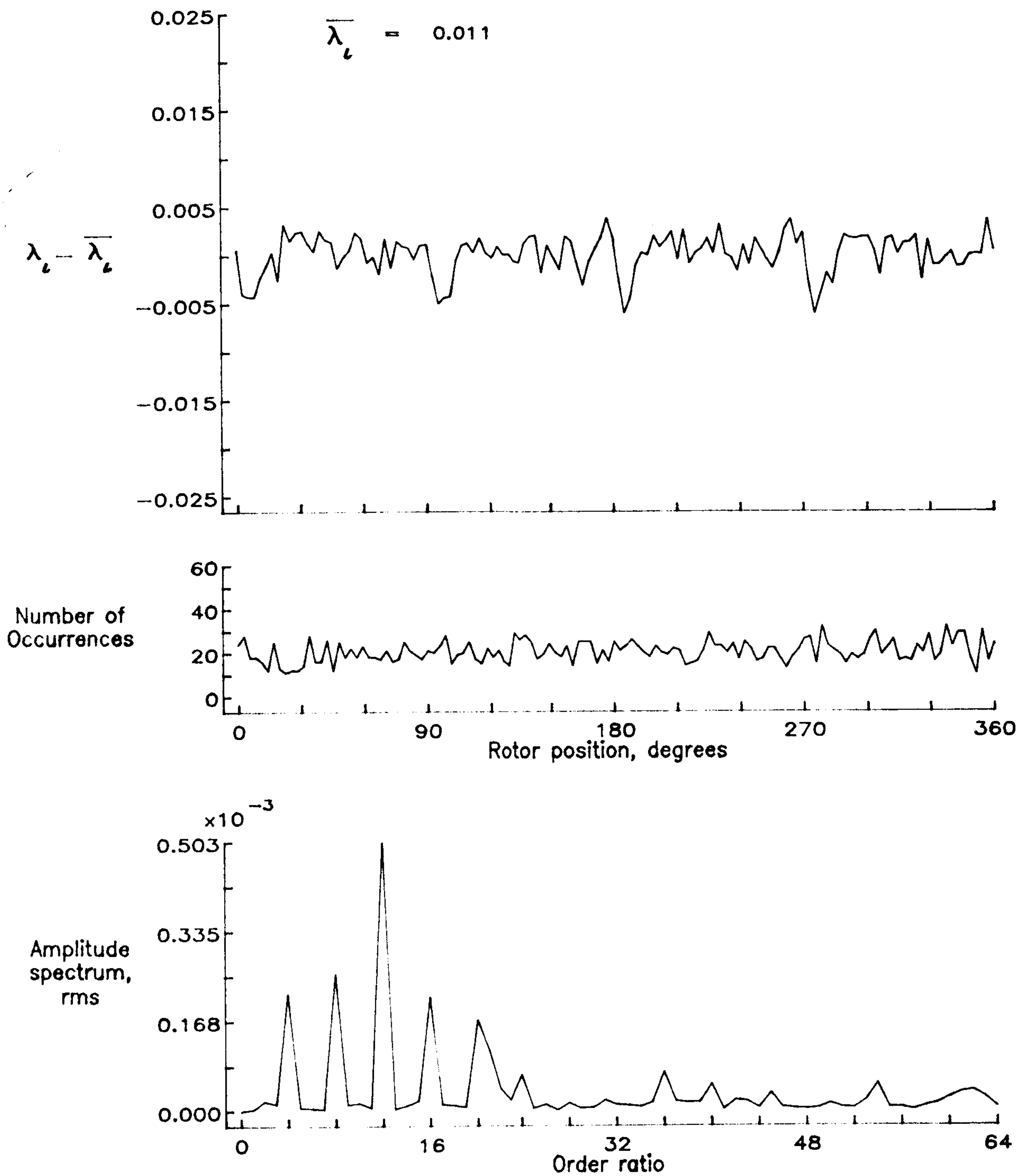


Figure 114.– Induced inflow velocity measured at 180 degrees and r/R of 0.98.



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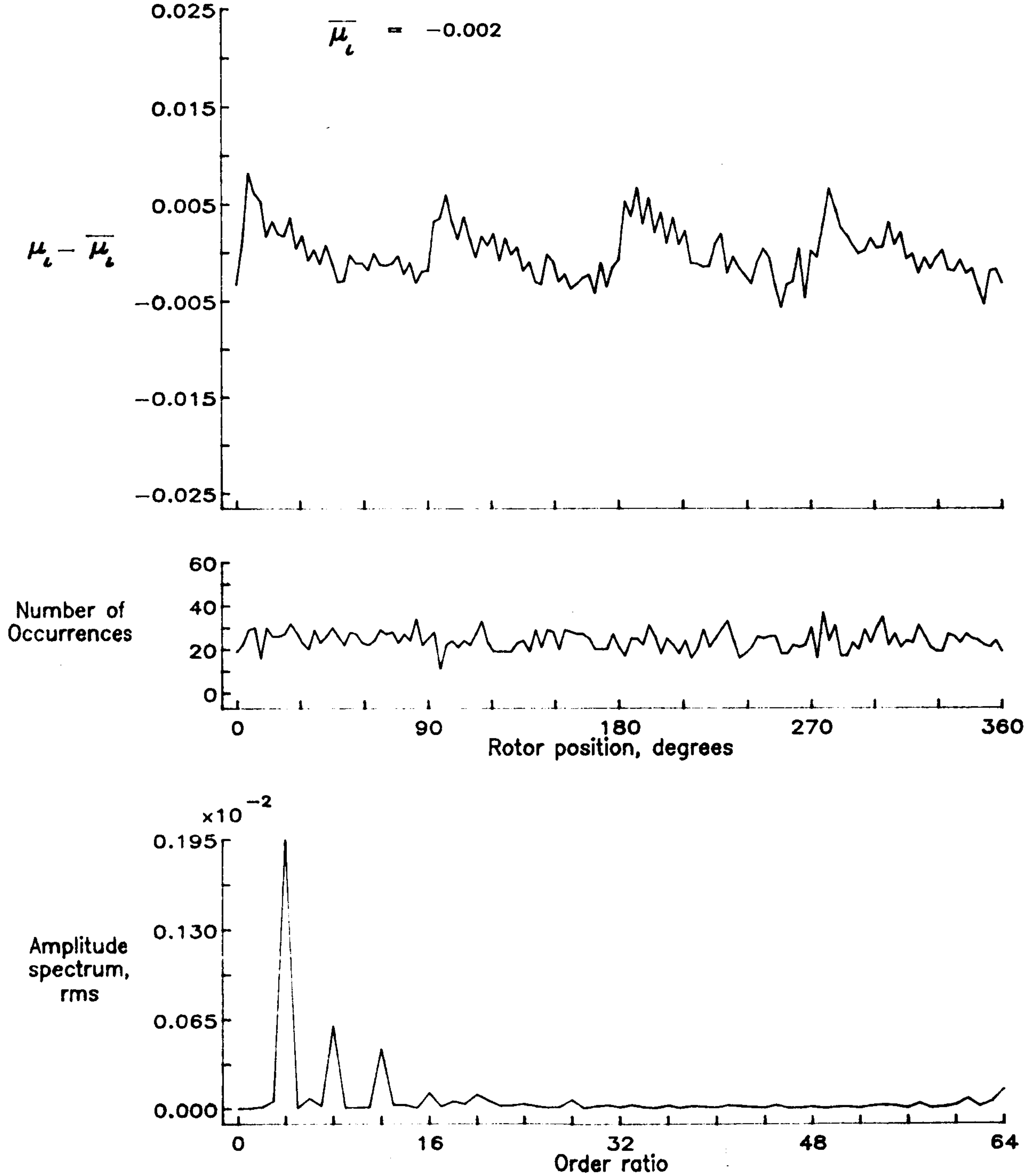
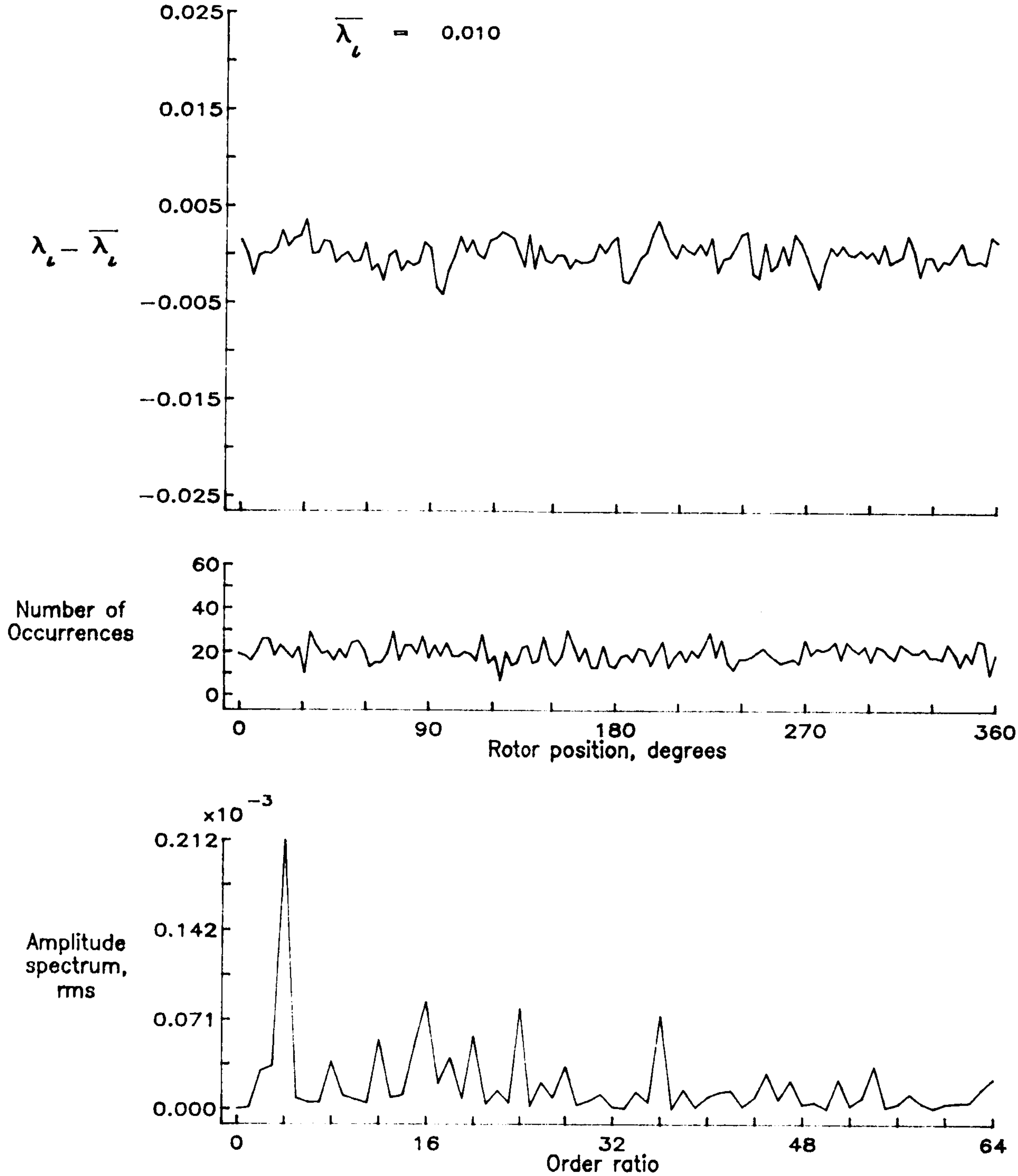


Figure 115.– Induced inflow velocity measured at 180 degrees and r/R of 1.02.



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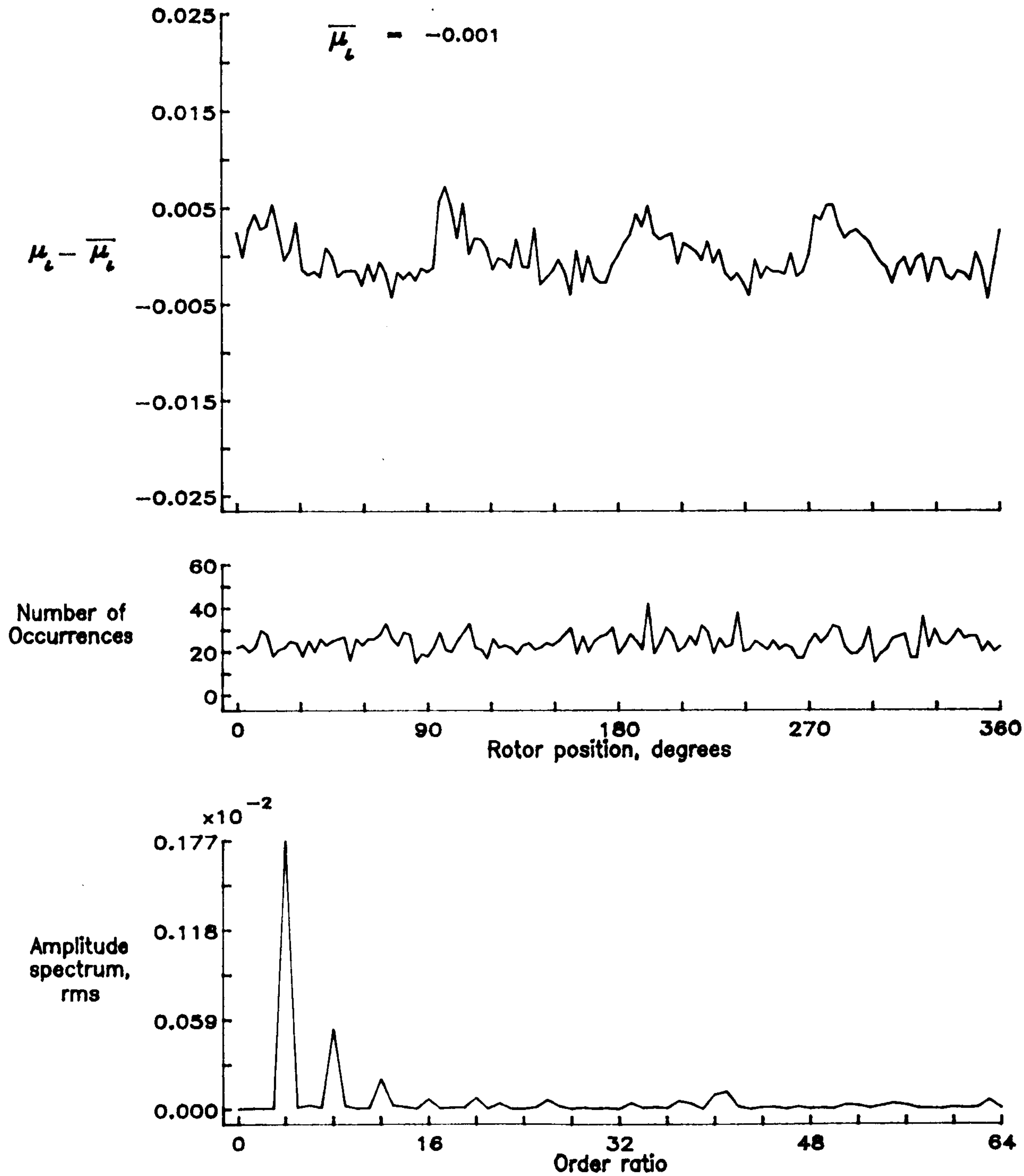
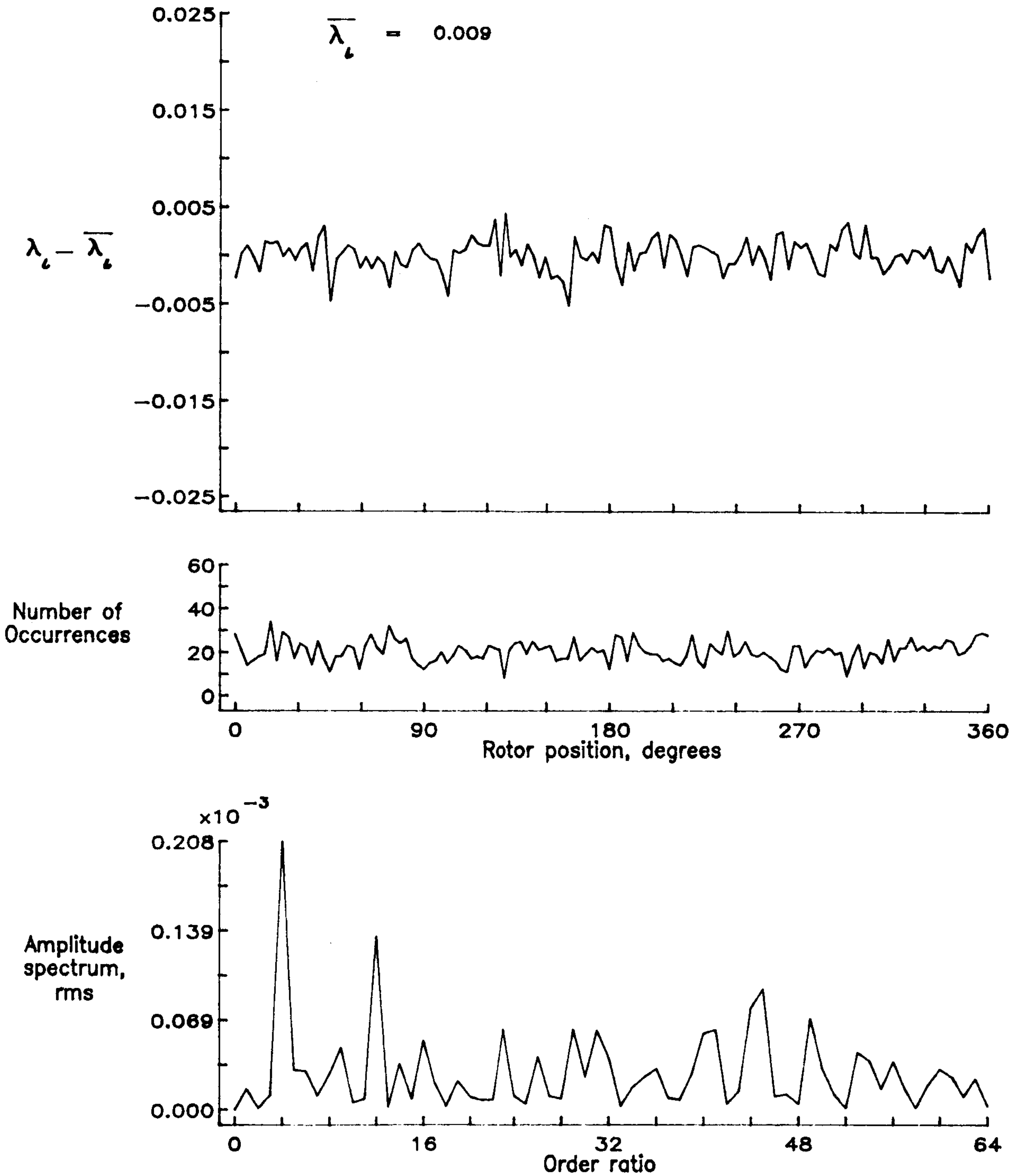


Figure 116.– Induced inflow velocity measured at 180 degrees and r/R of 1.04.



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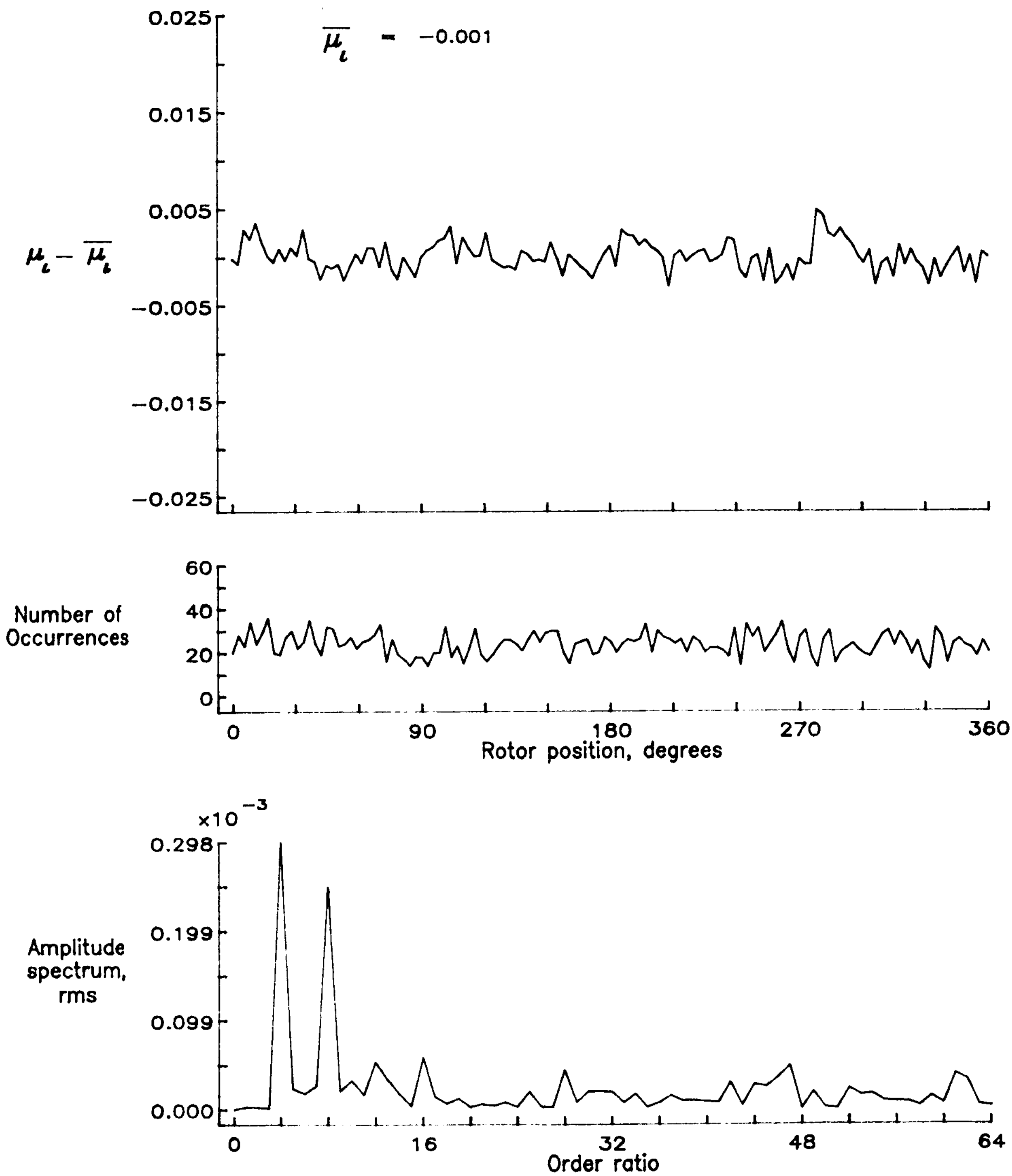
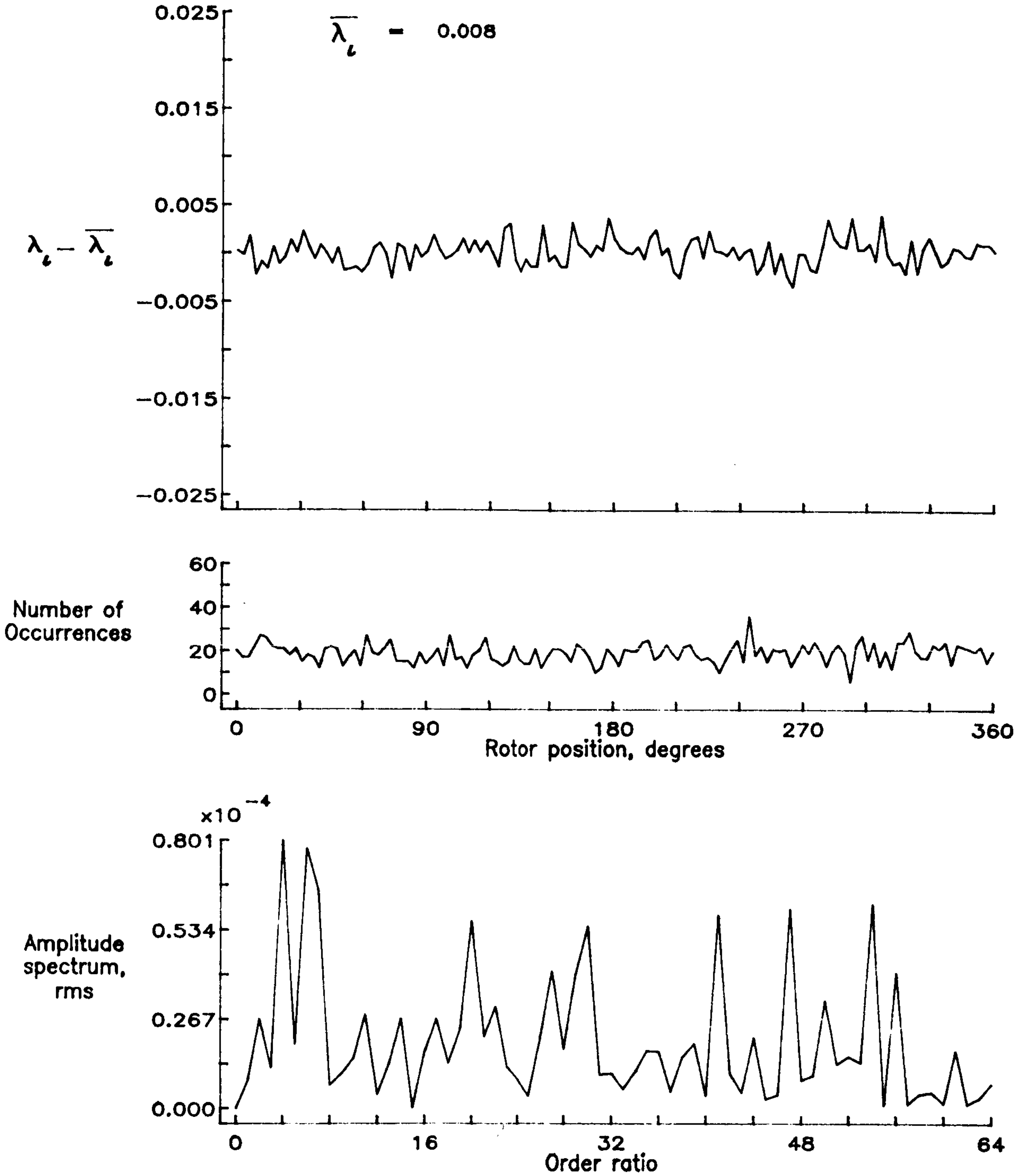


Figure 117.– Induced inflow velocity measured at 180 degrees and r/R of 1.10.



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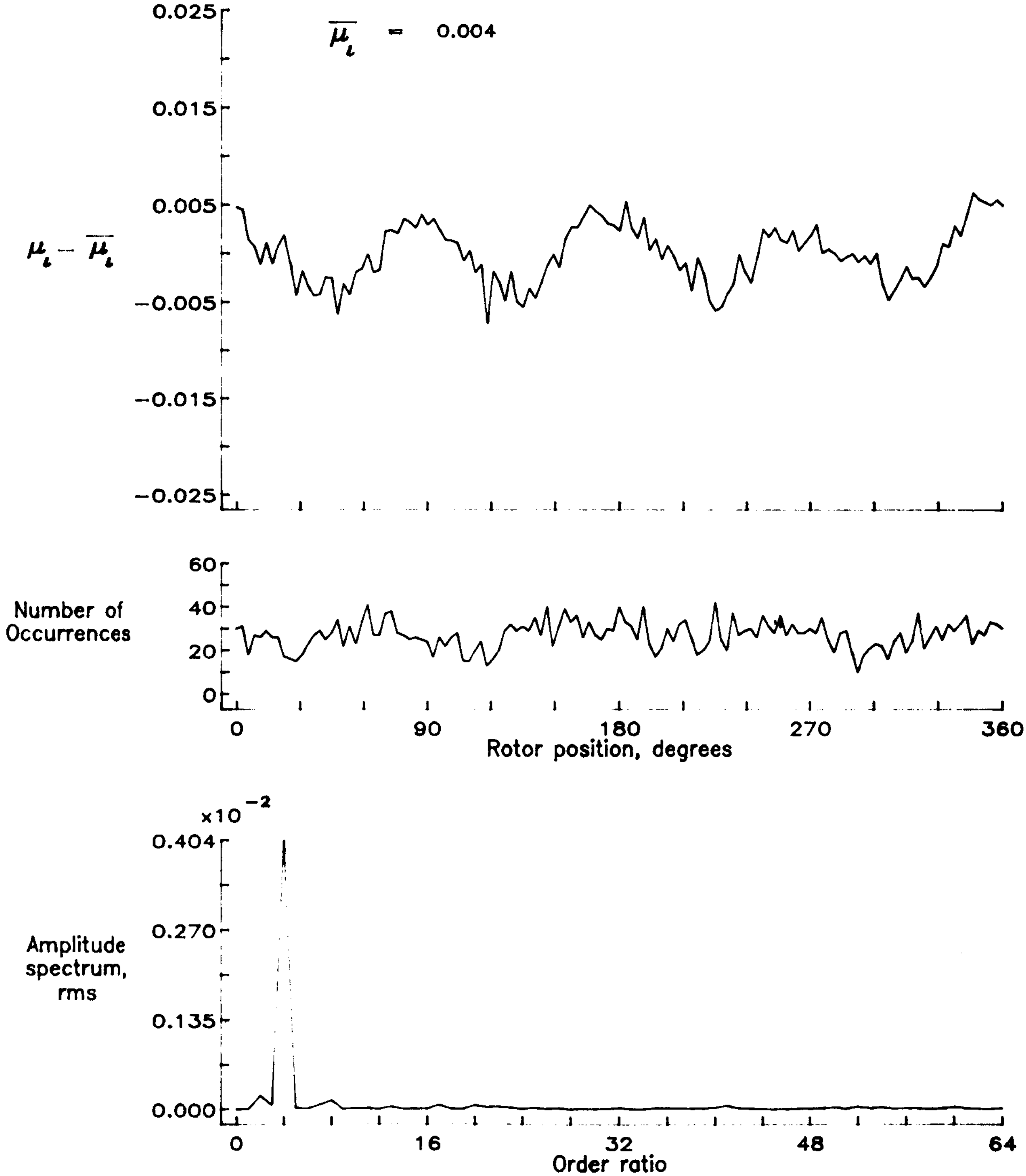
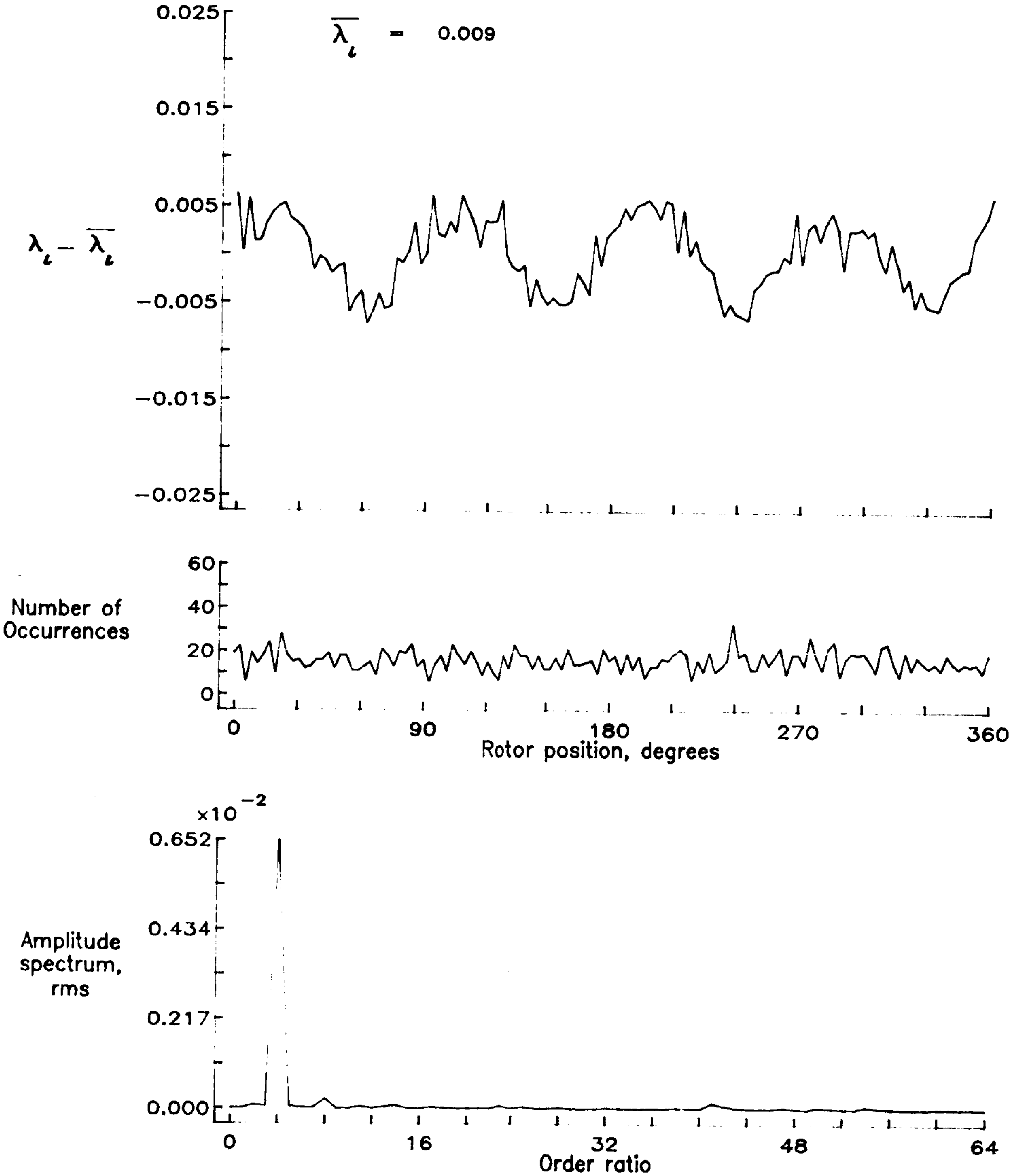


Figure 118.– Induced inflow velocity measured at 210 degrees and r/R of 0.20.



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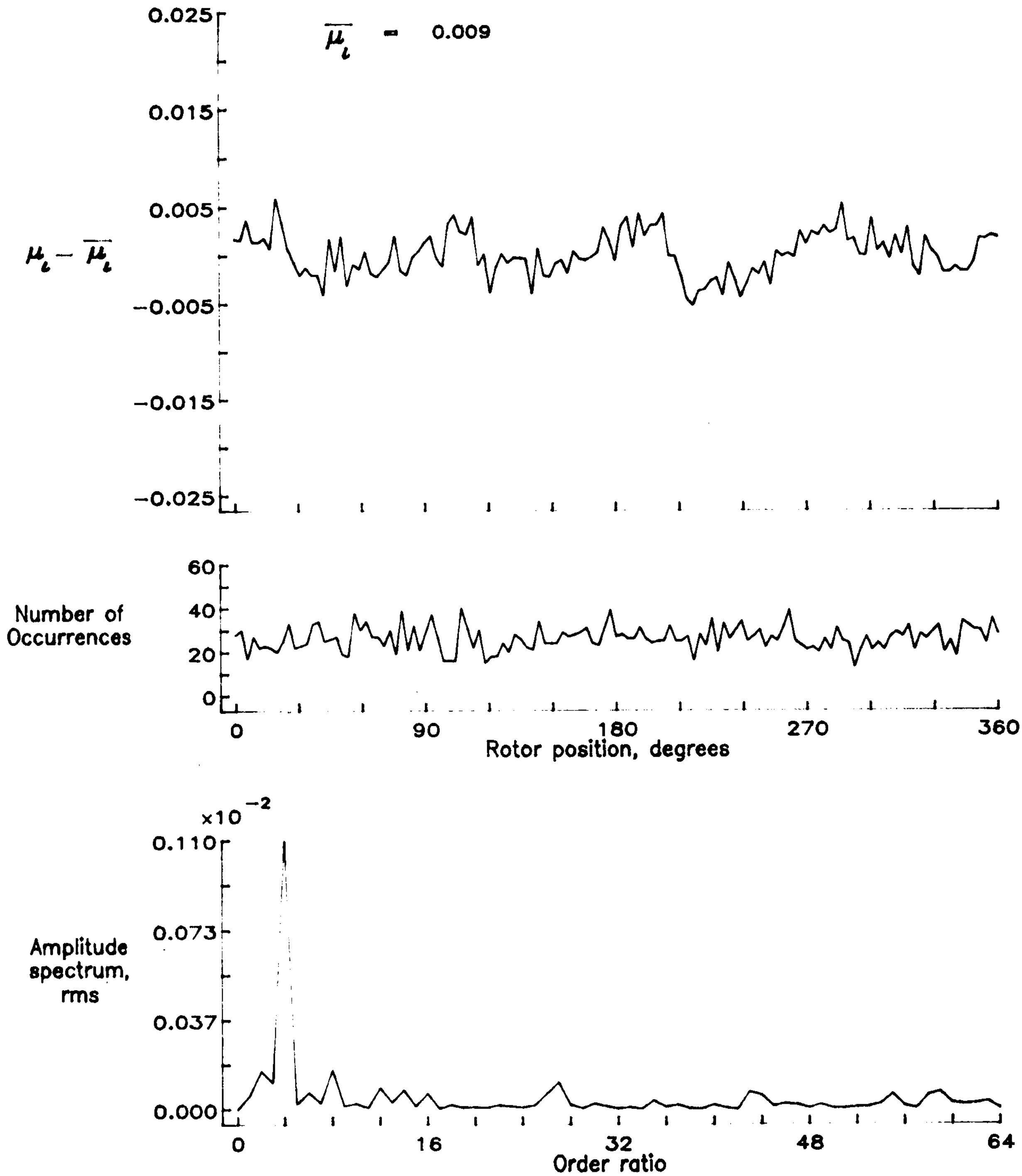

Figure 119.– Induced inflow velocity measured at 210 degrees and r/R of 0.40.

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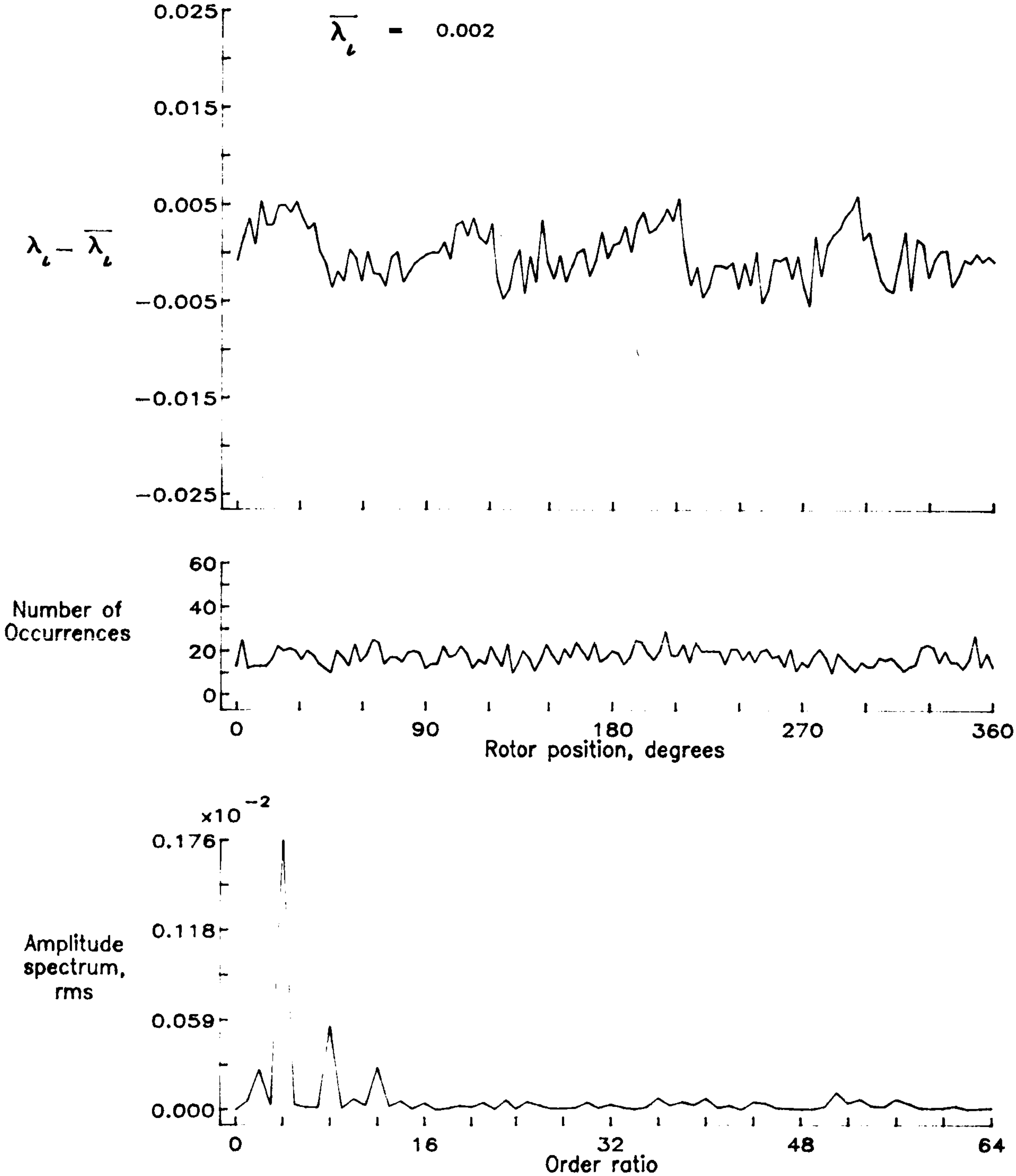

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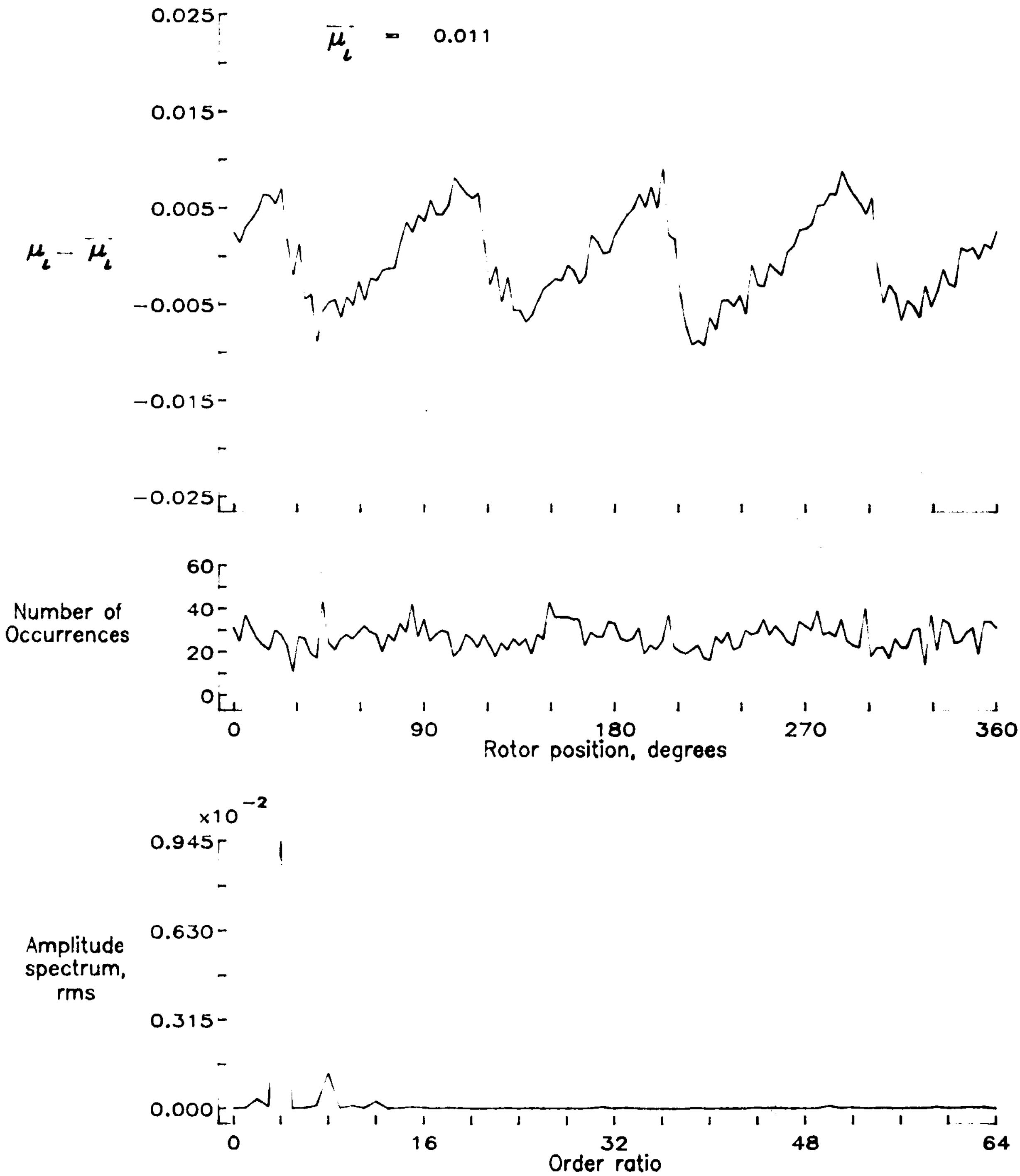

Figure 120.– Induced inflow velocity measured at 210 degrees and r/R of 0.50.

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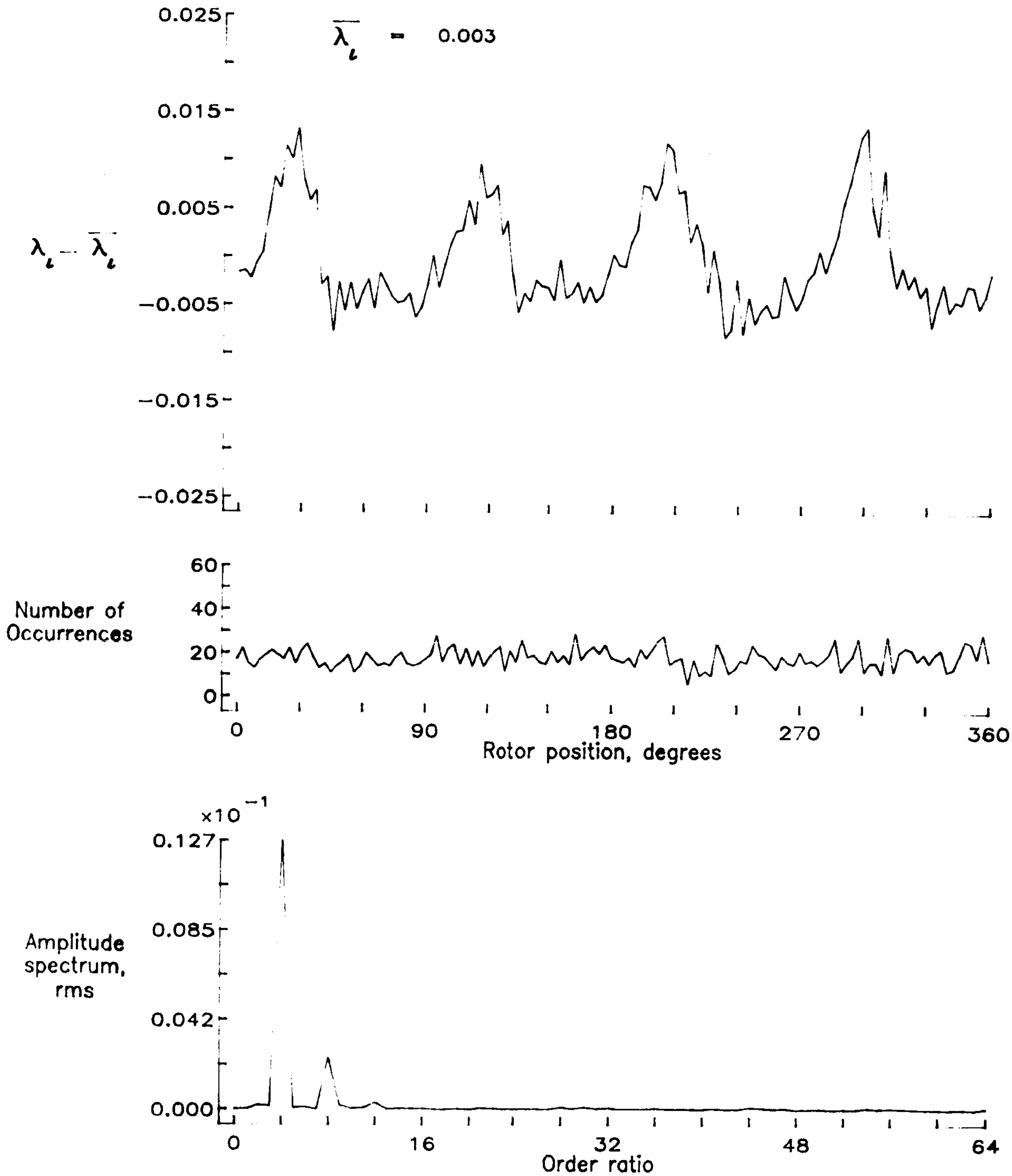

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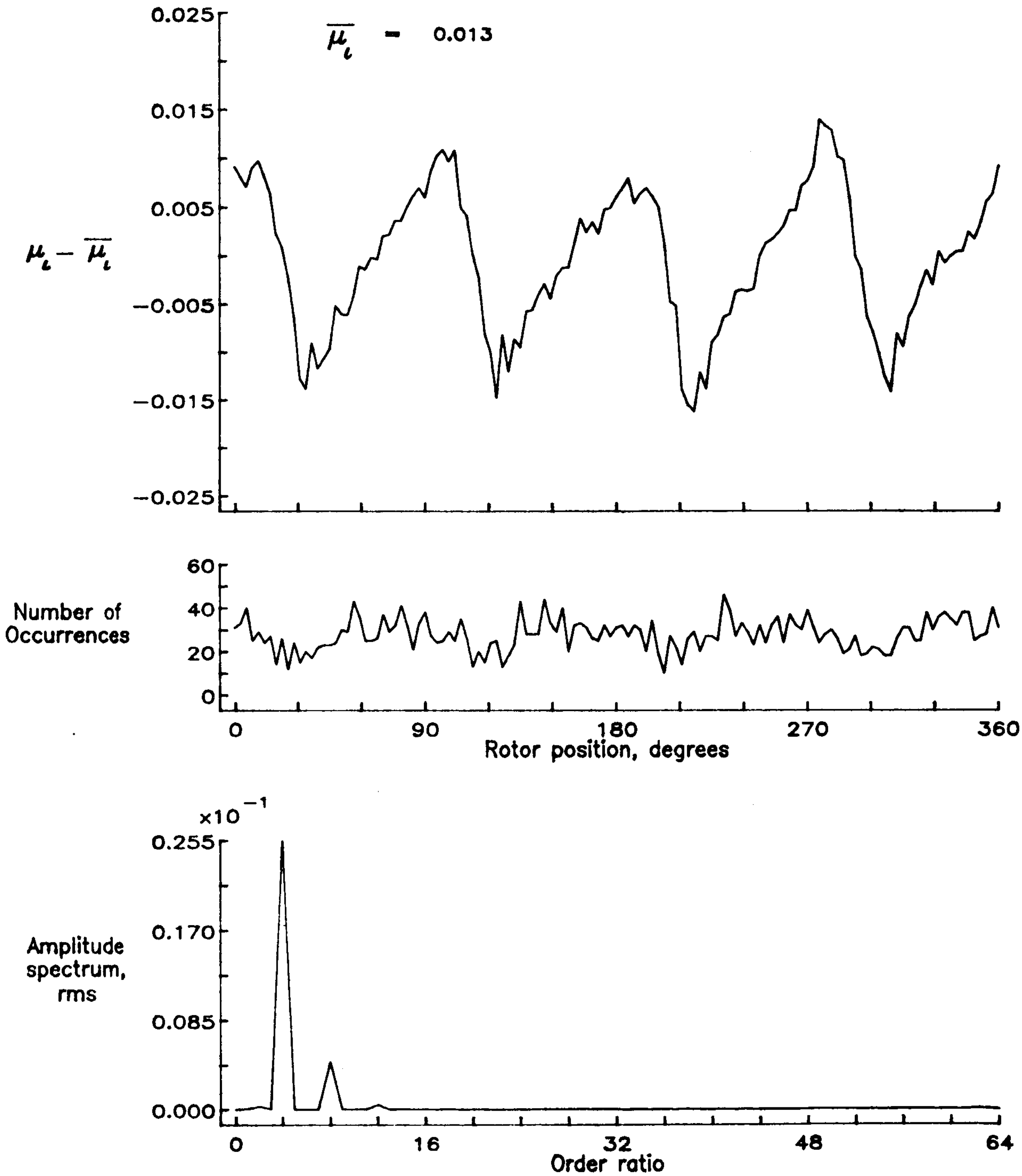
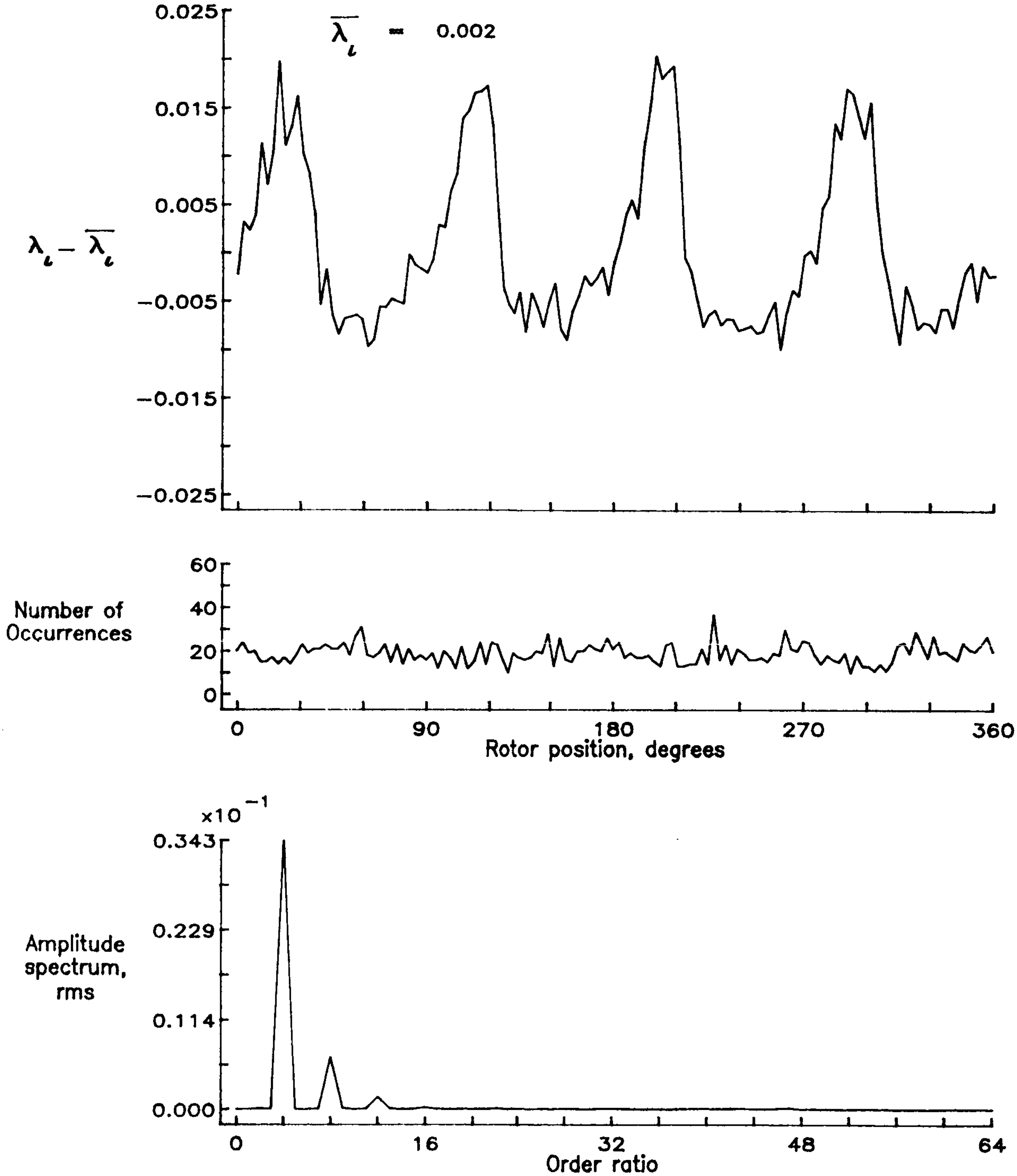


Figure 121.– Induced inflow velocity measured at 210 degrees and r/R of 0.60.



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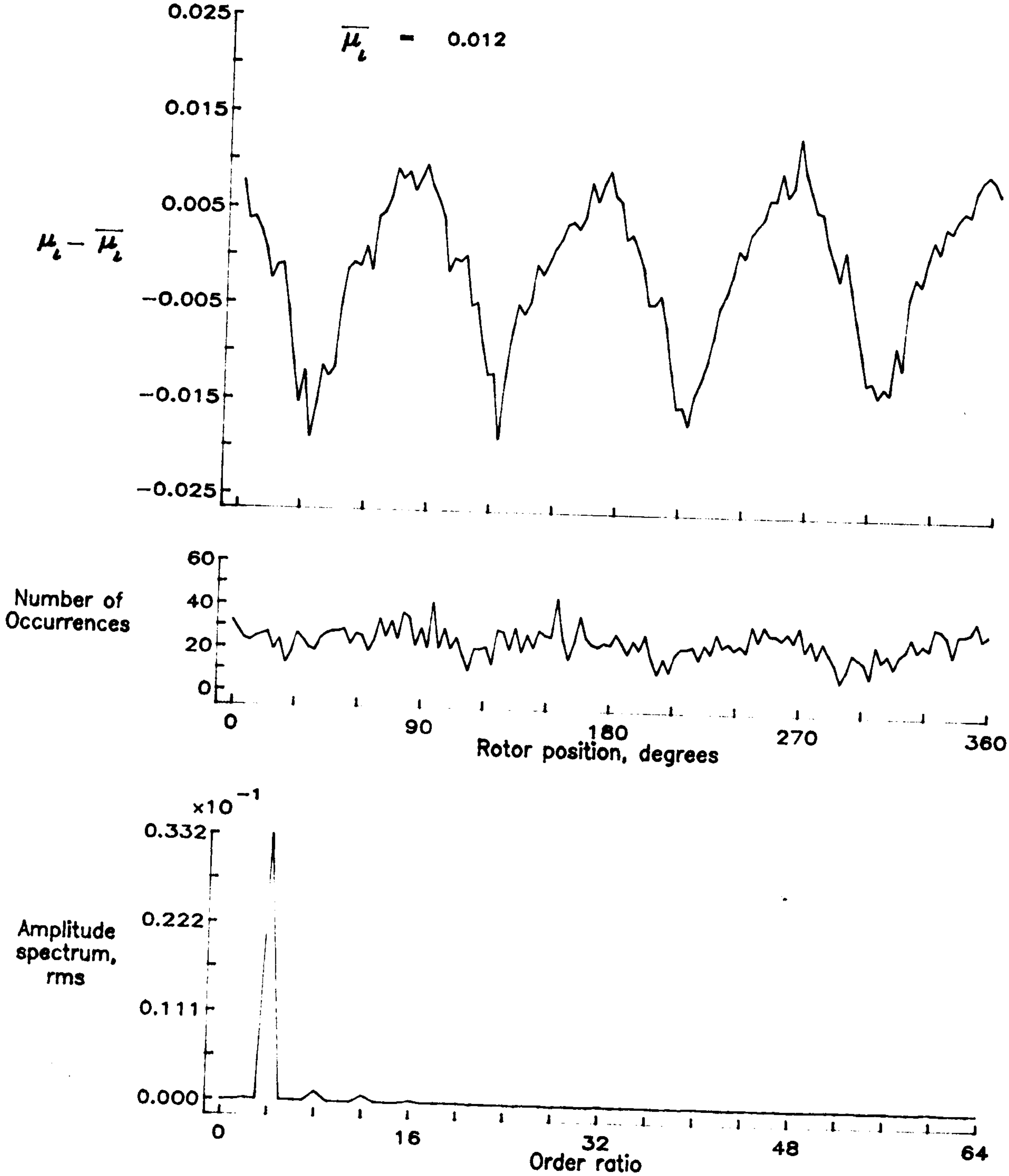
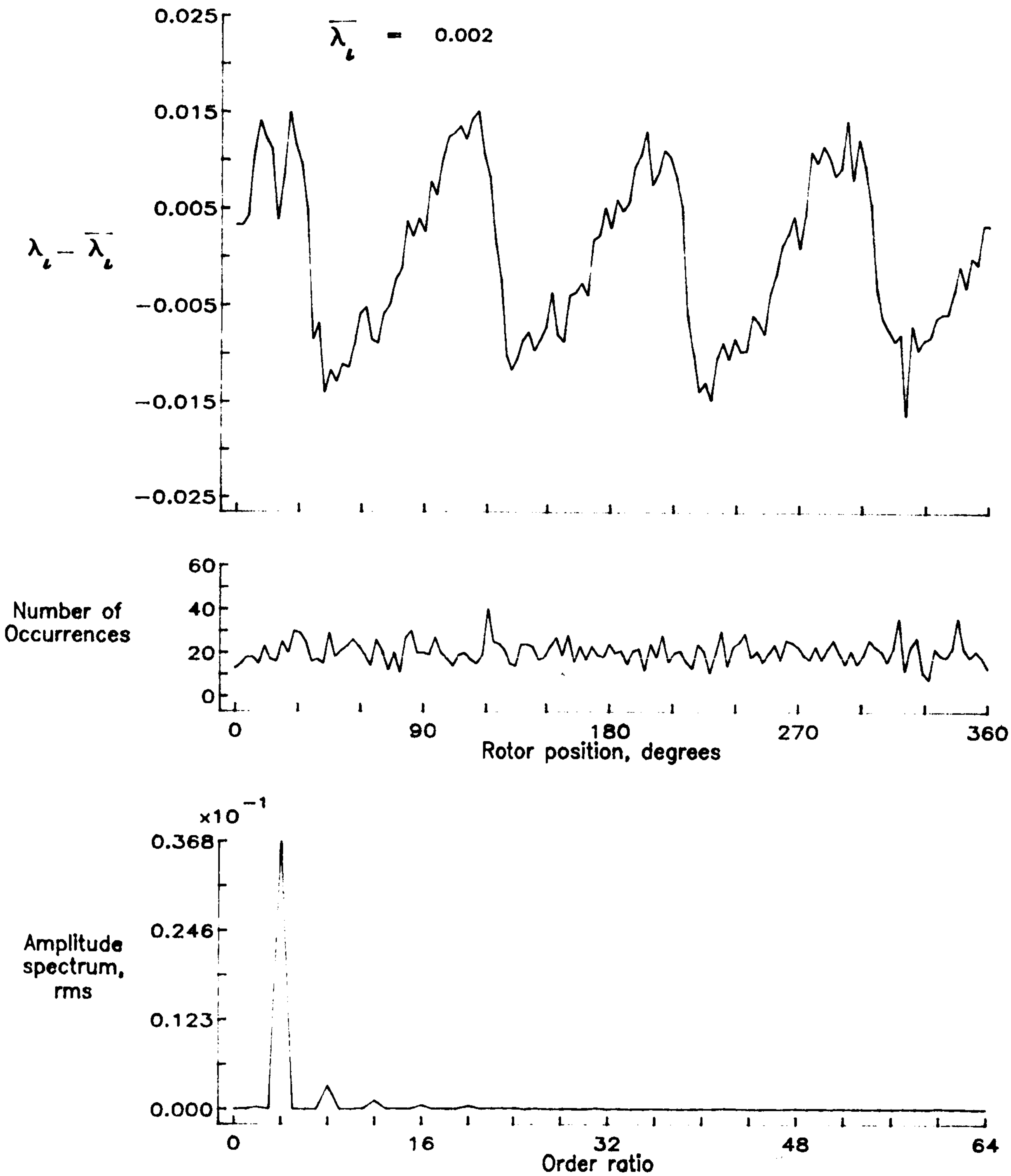


Figure 122.– Induced inflow velocity measured at 210 degrees and r/R of 0.70.



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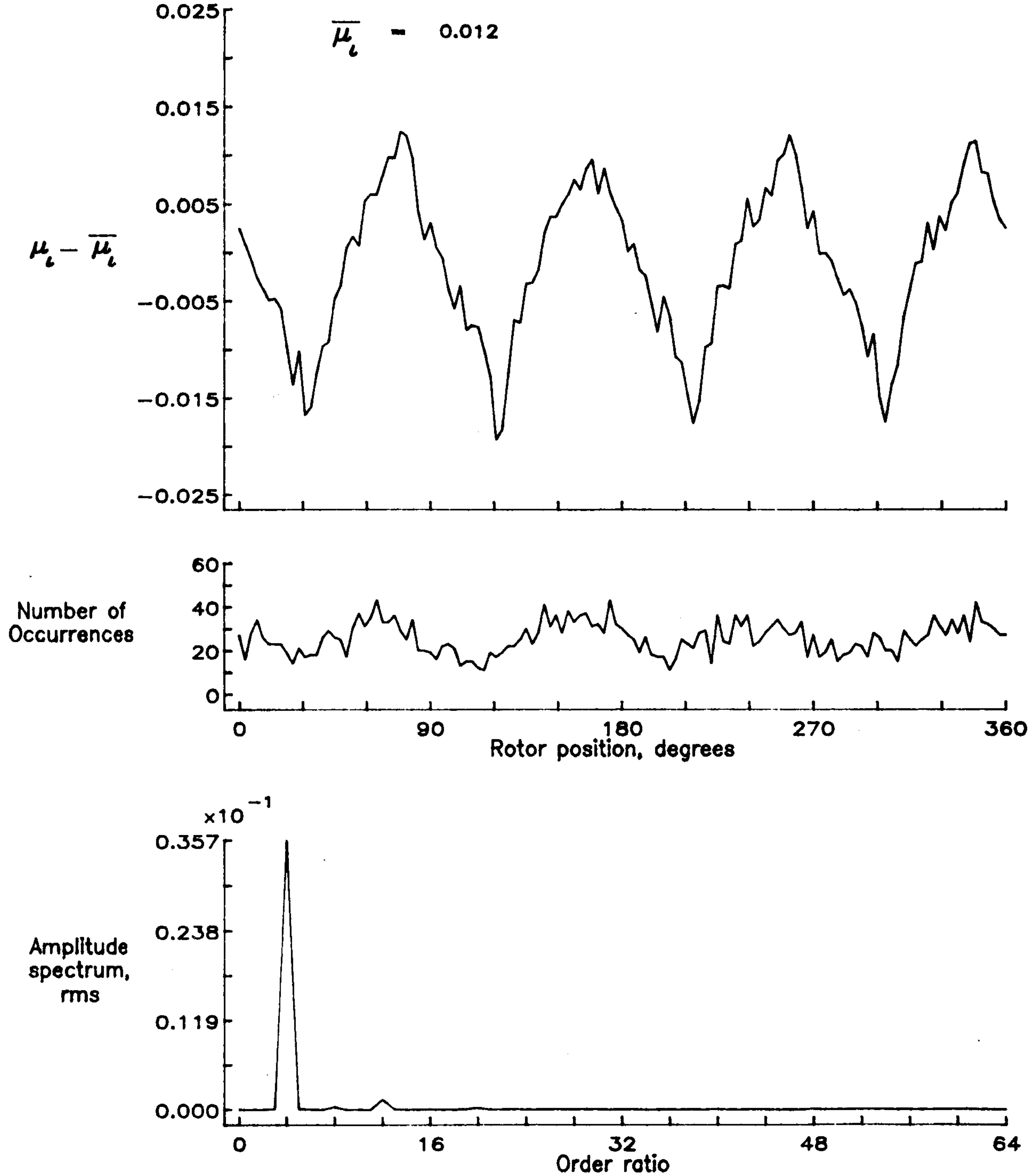
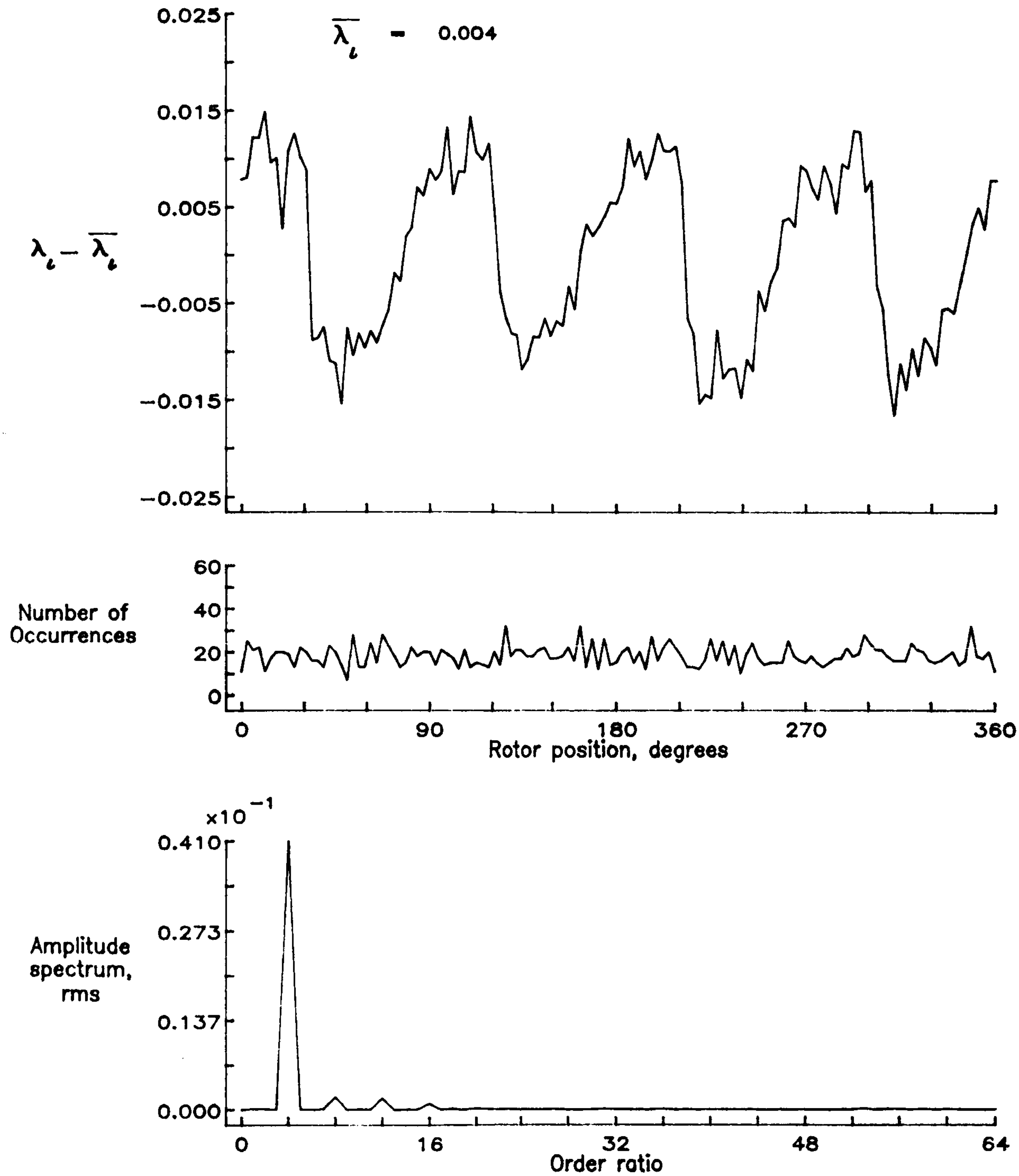


Figure 123.— Induced inflow velocity measured at 210 degrees and r/R of 0.74.



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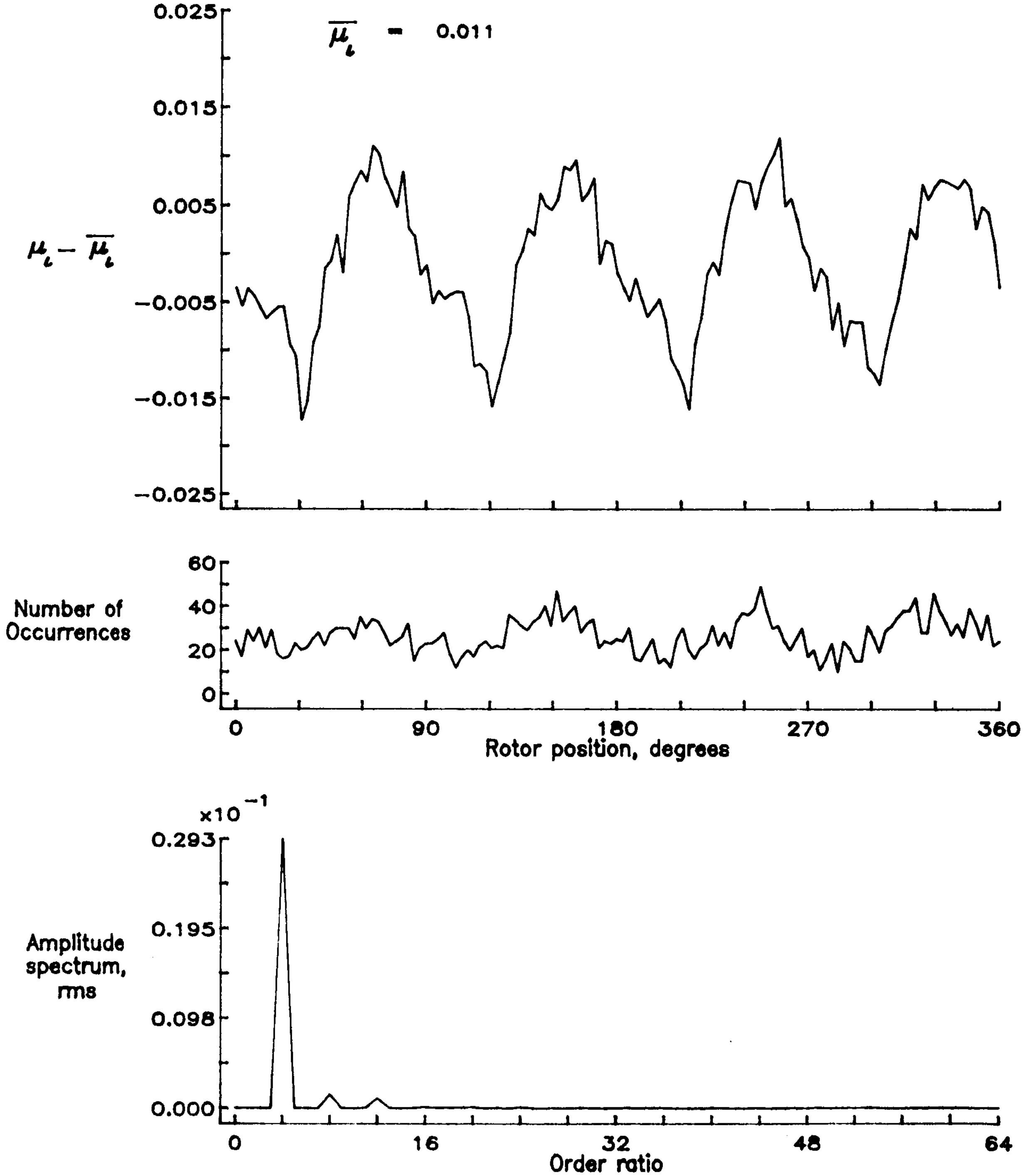
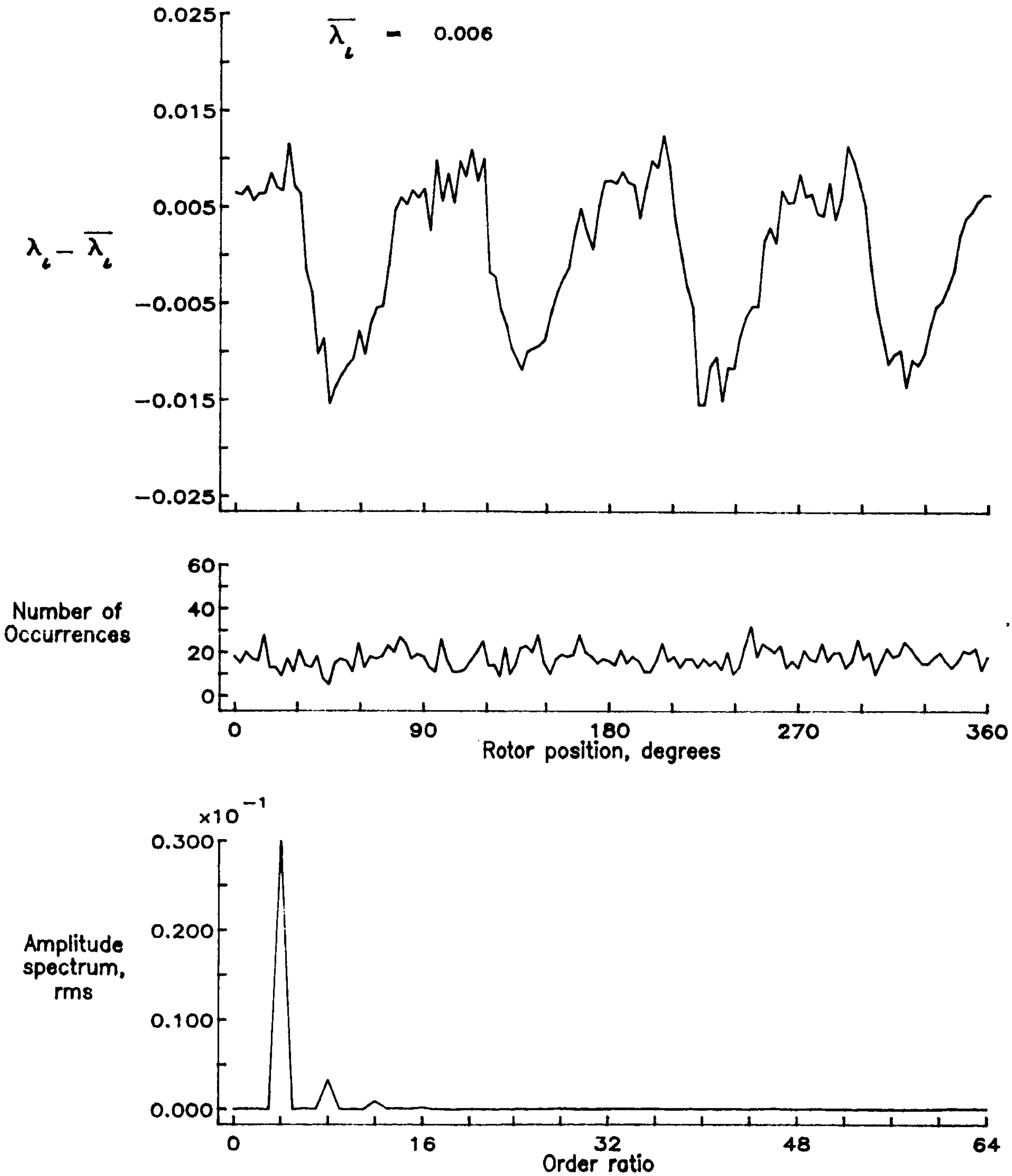


Figure 124.– Induced inflow velocity measured at 210 degrees and r/R of 0.78.



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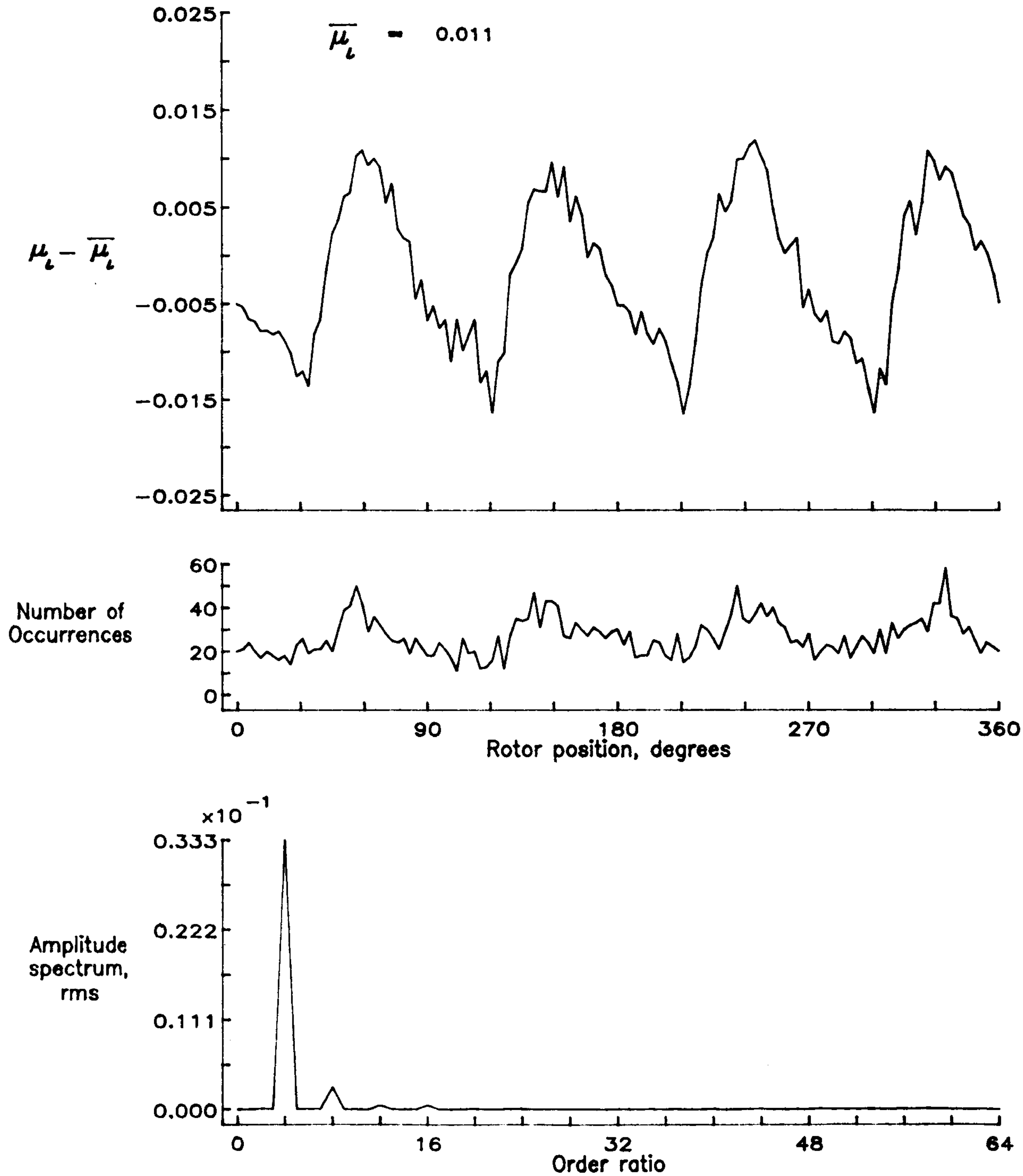
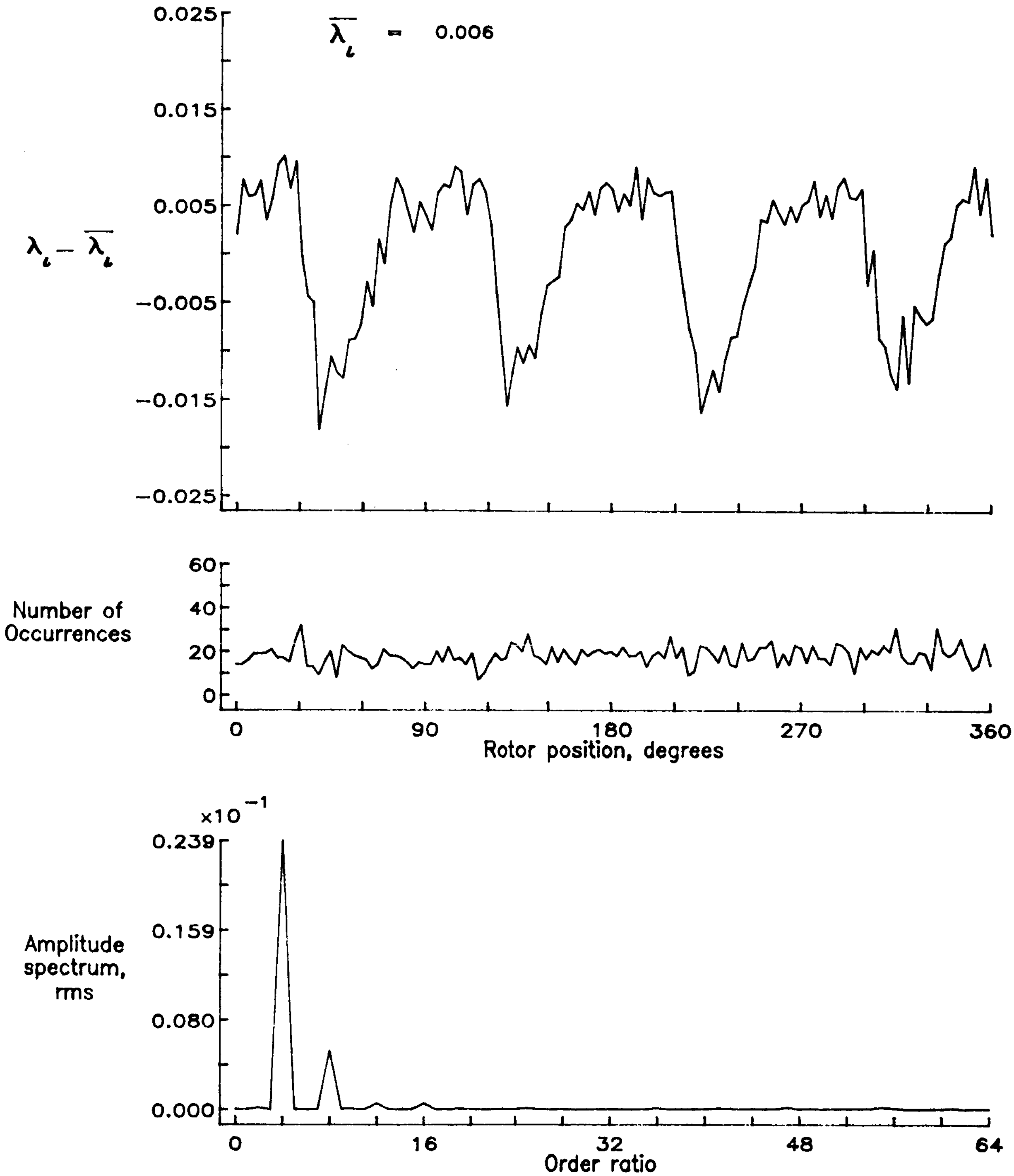


Figure 125.– Induced inflow velocity measured at 210 degrees and r/R of 0.82.



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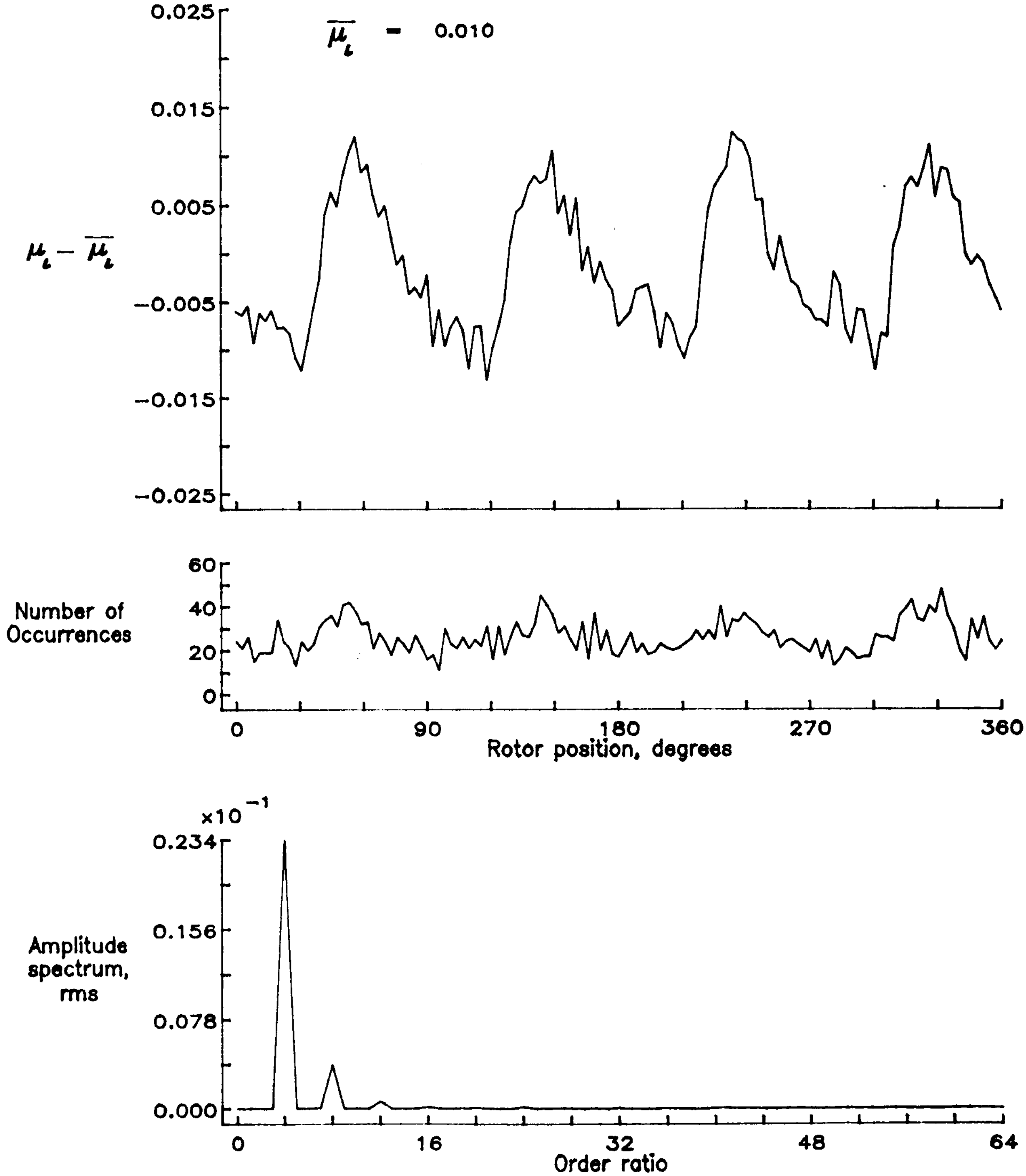
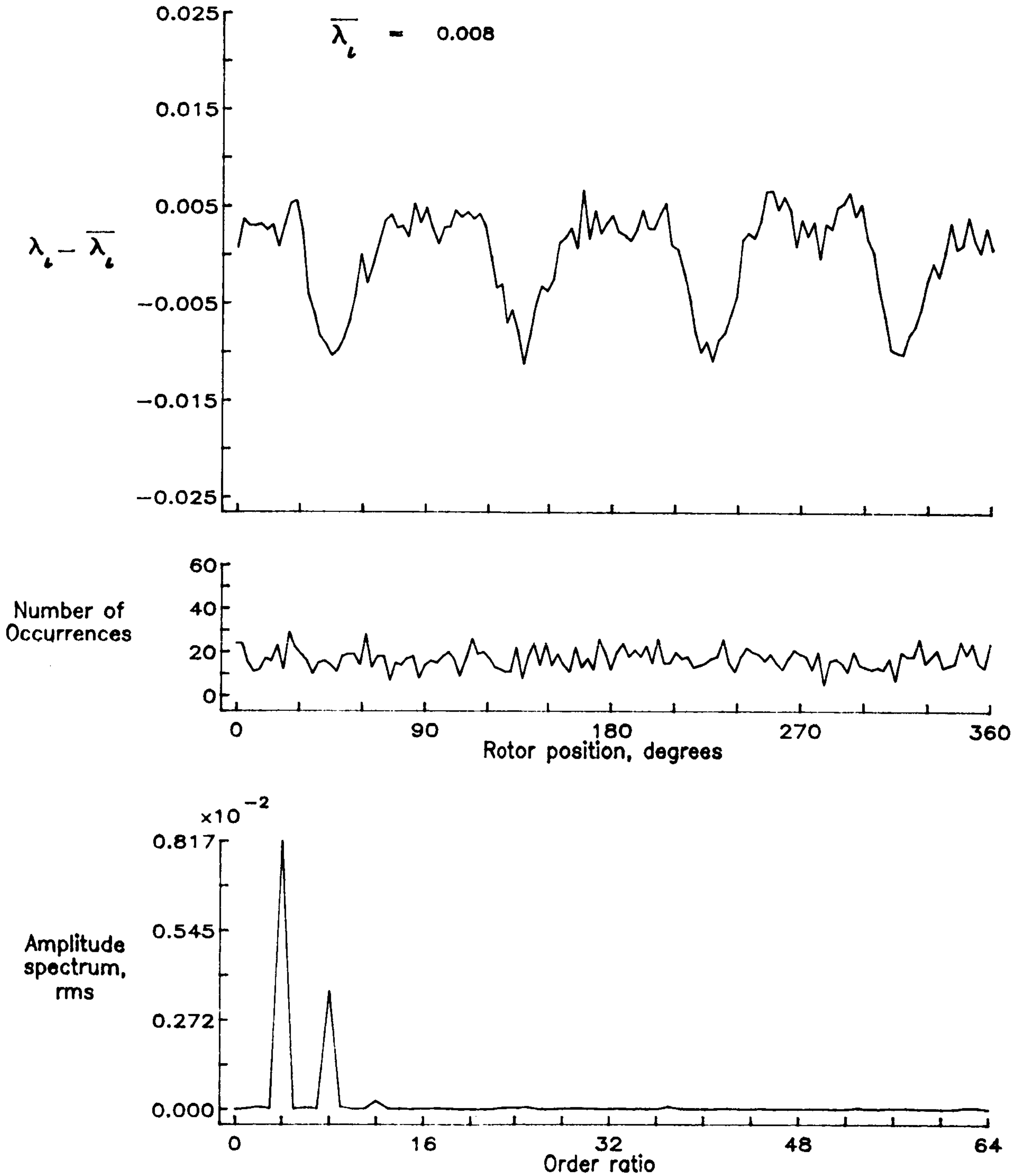


Figure 126.— Induced inflow velocity measured at 210 degrees and r/R of 0.86.



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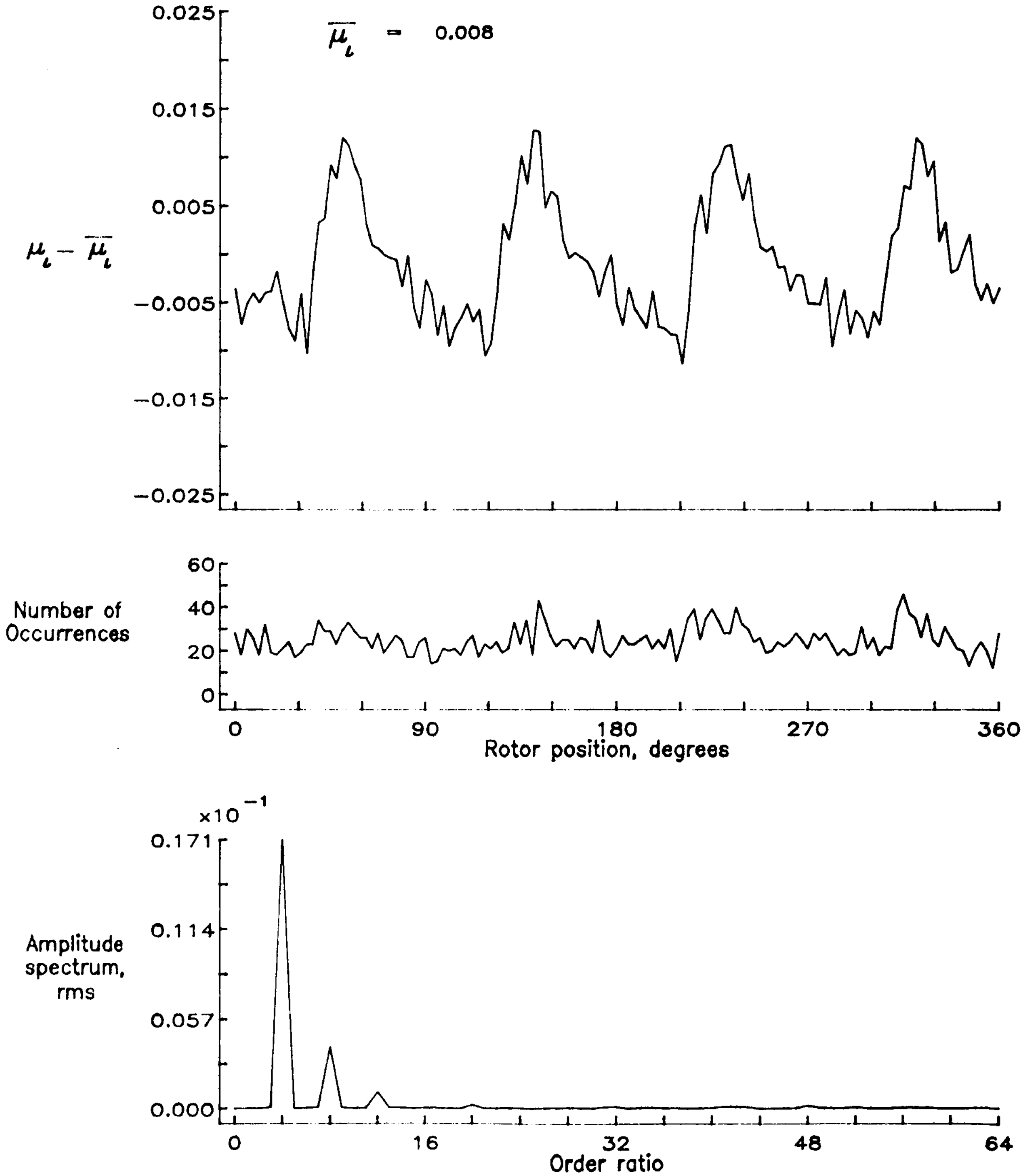
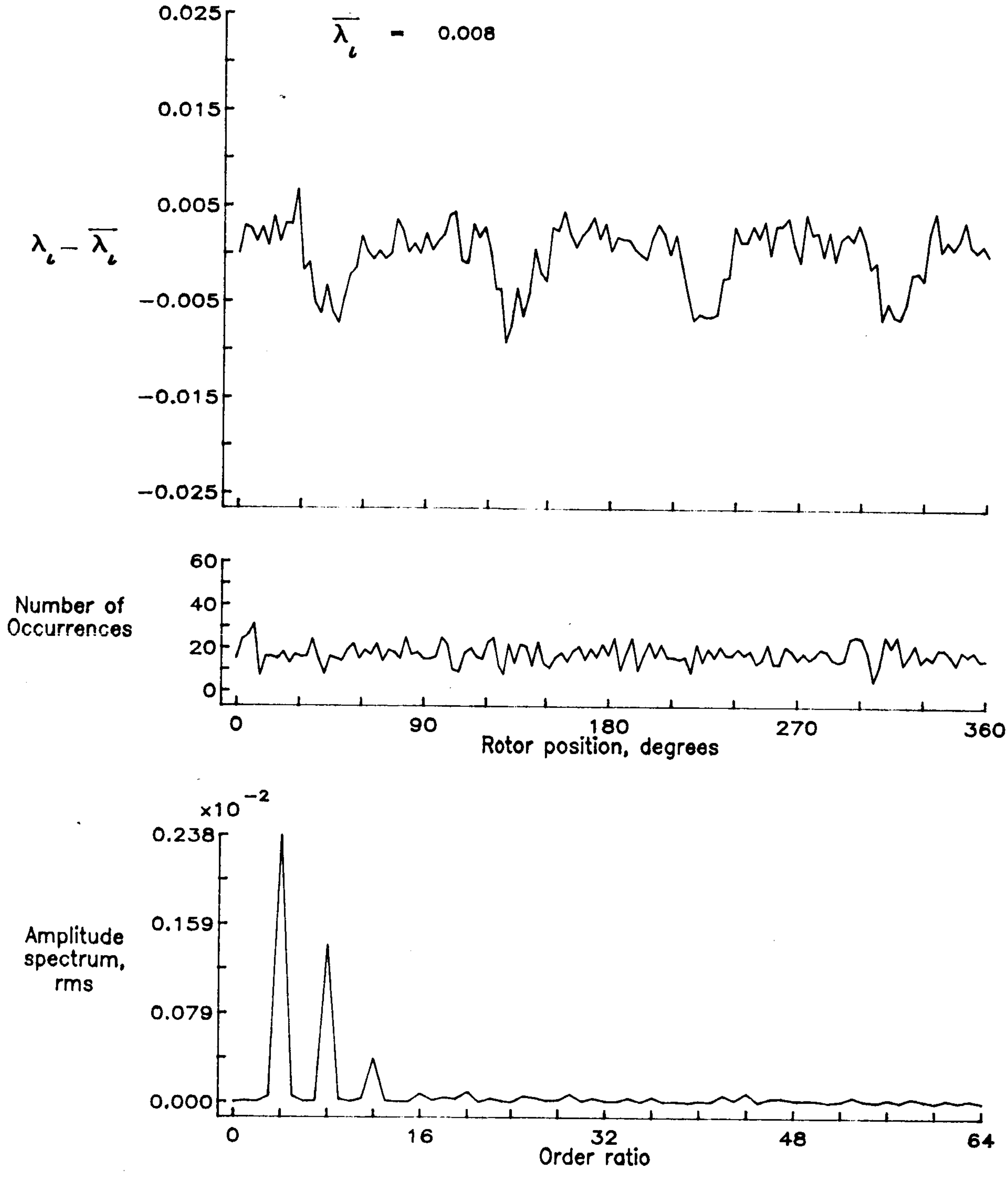


Figure 127.— Induced inflow velocity measured at 210 degrees and r/R of 0.90.



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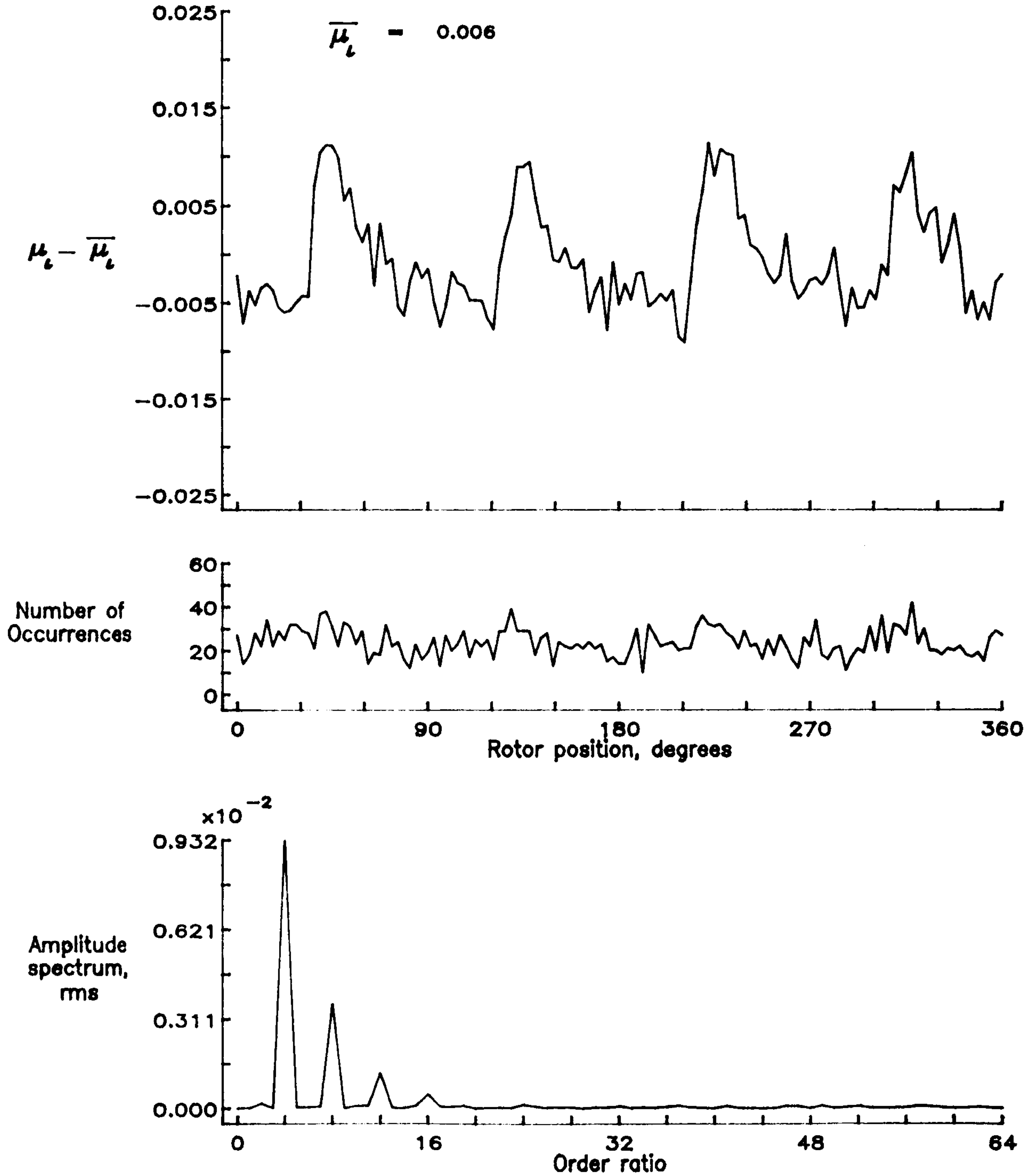
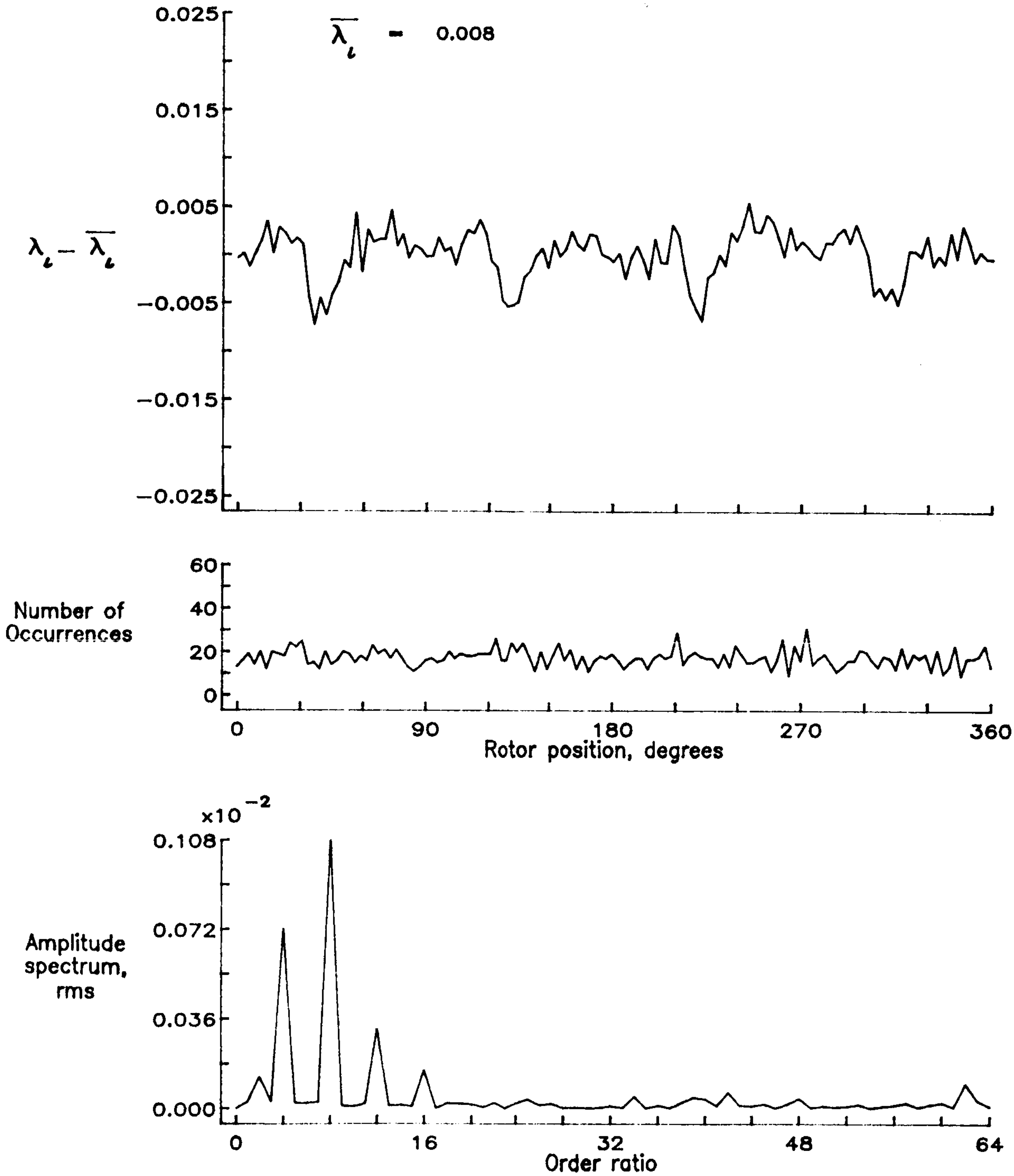


Figure 128.— Induced inflow velocity measured at 210 degrees and r/R of 0.94.



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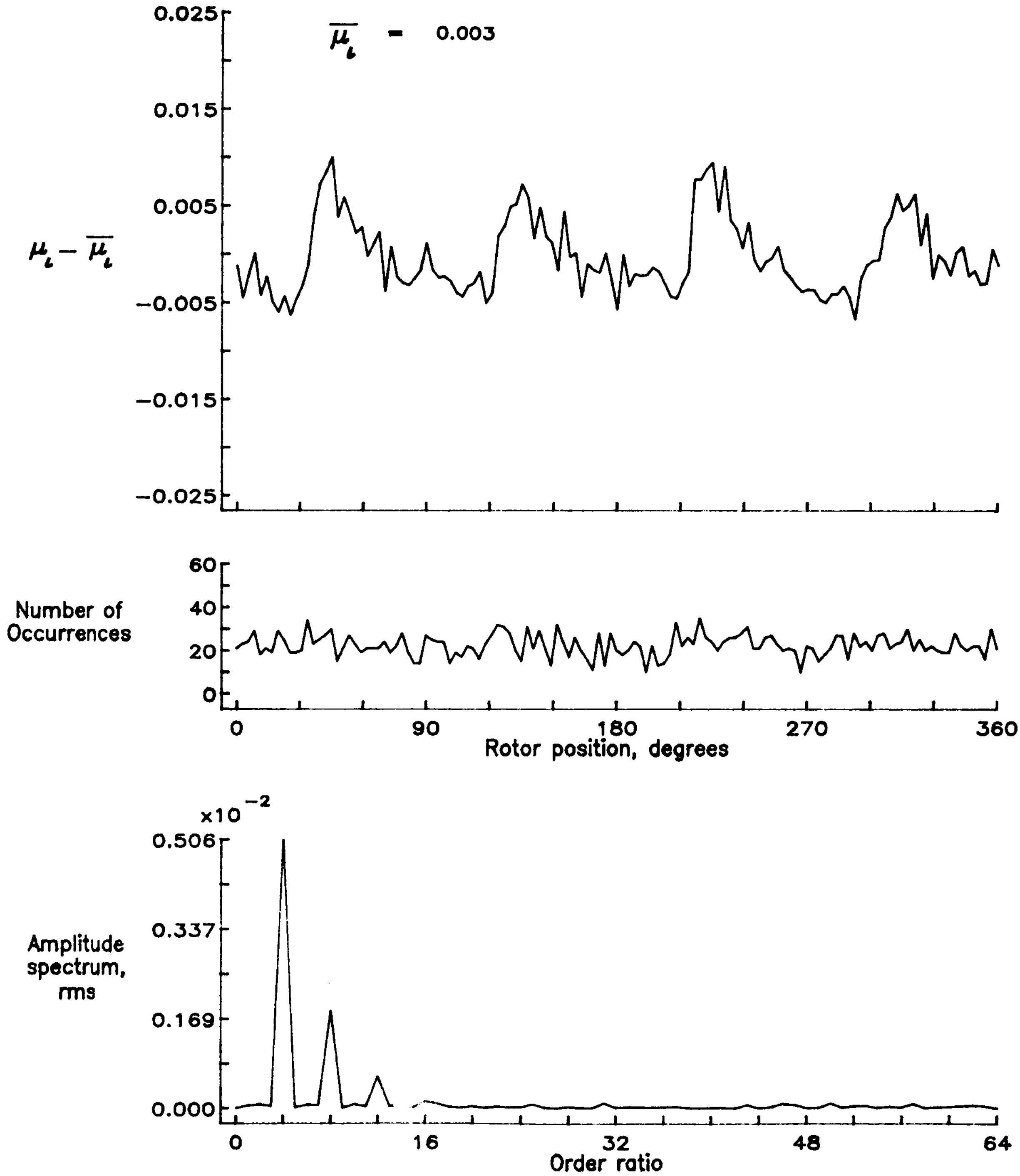
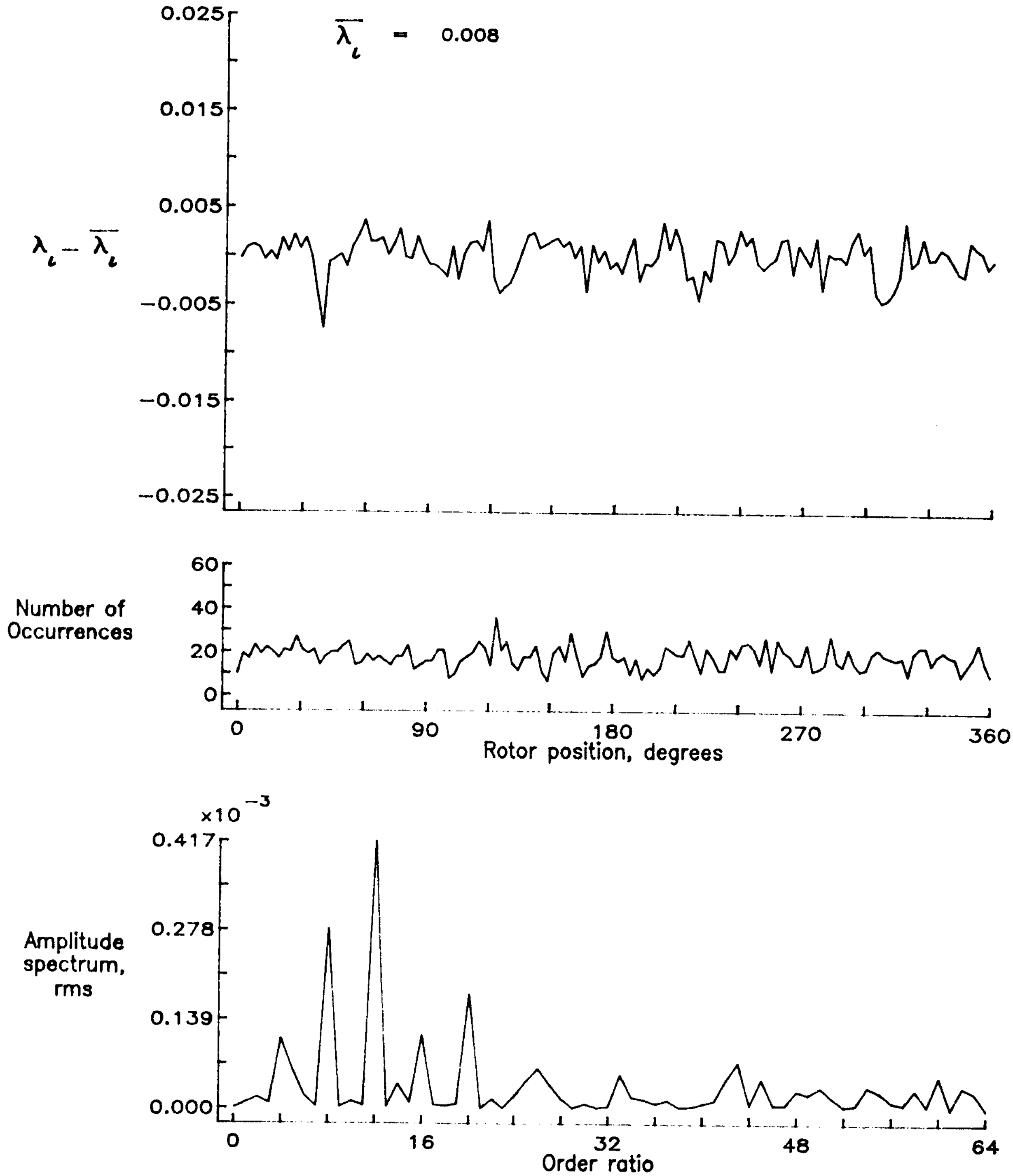


Figure 129.— Induced inflow velocity measured at 210 degrees and r/R of 0.98.



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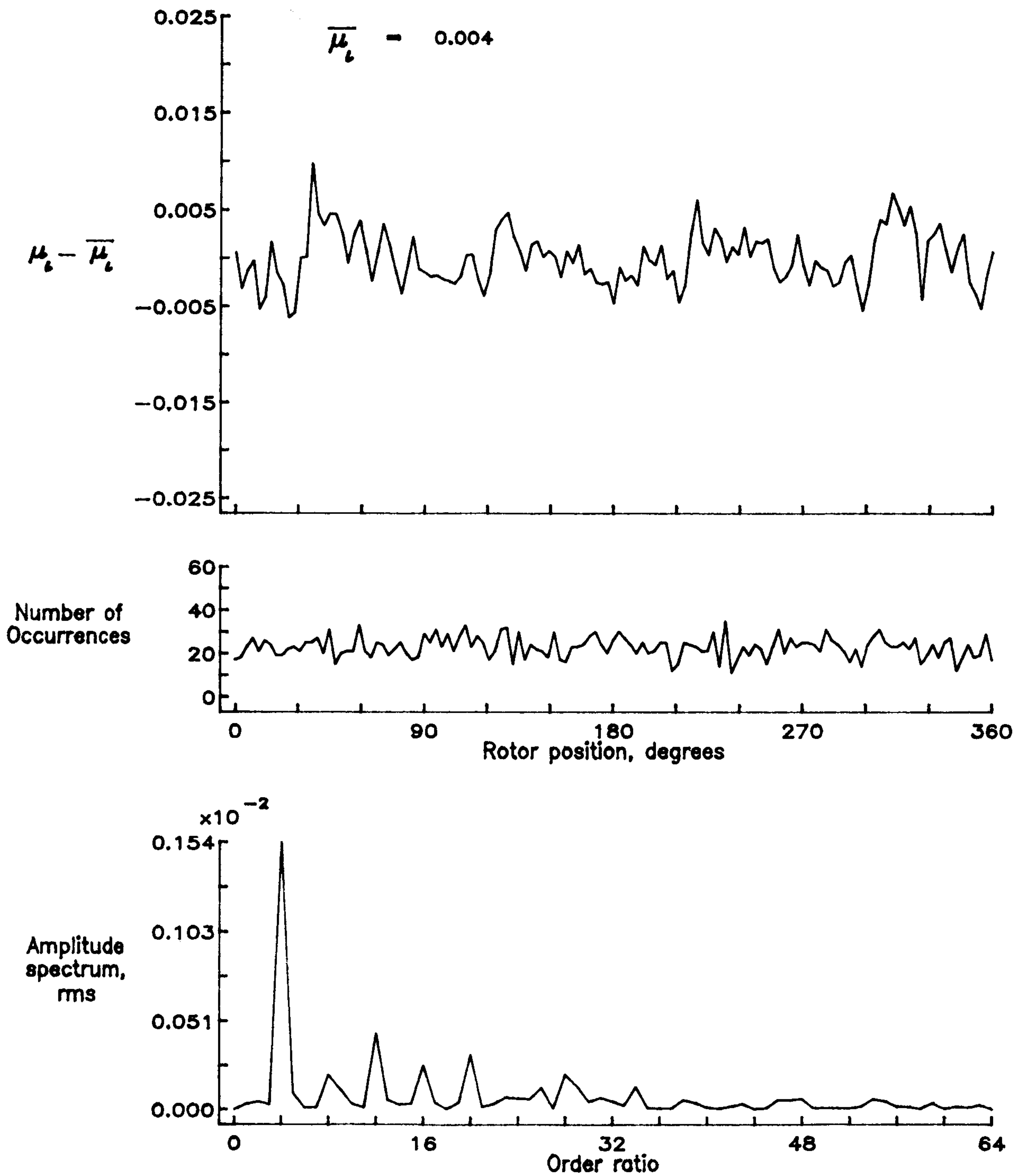
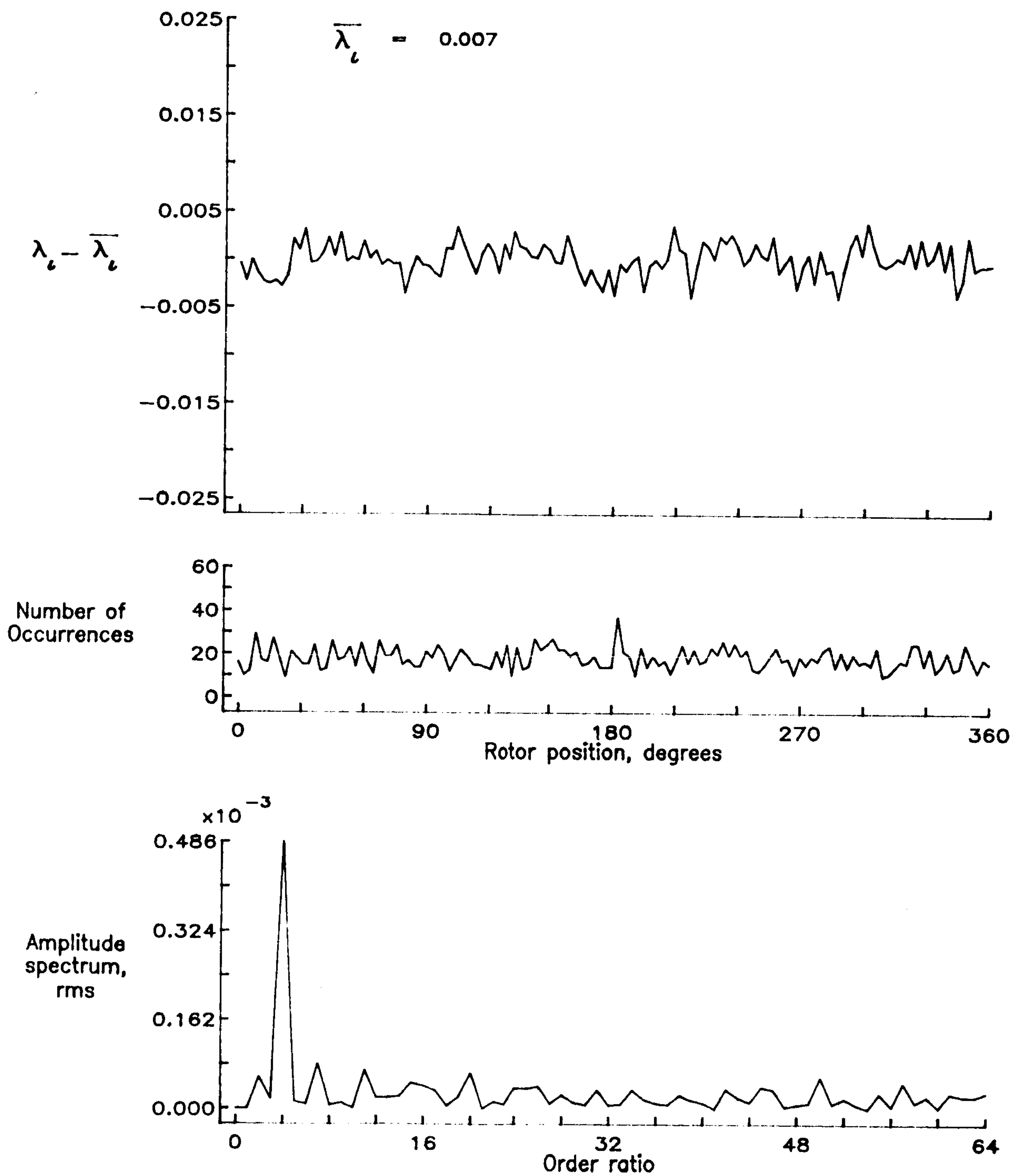


Figure 130.– Induced inflow velocity measured at 210 degrees and r/R of 1.02.



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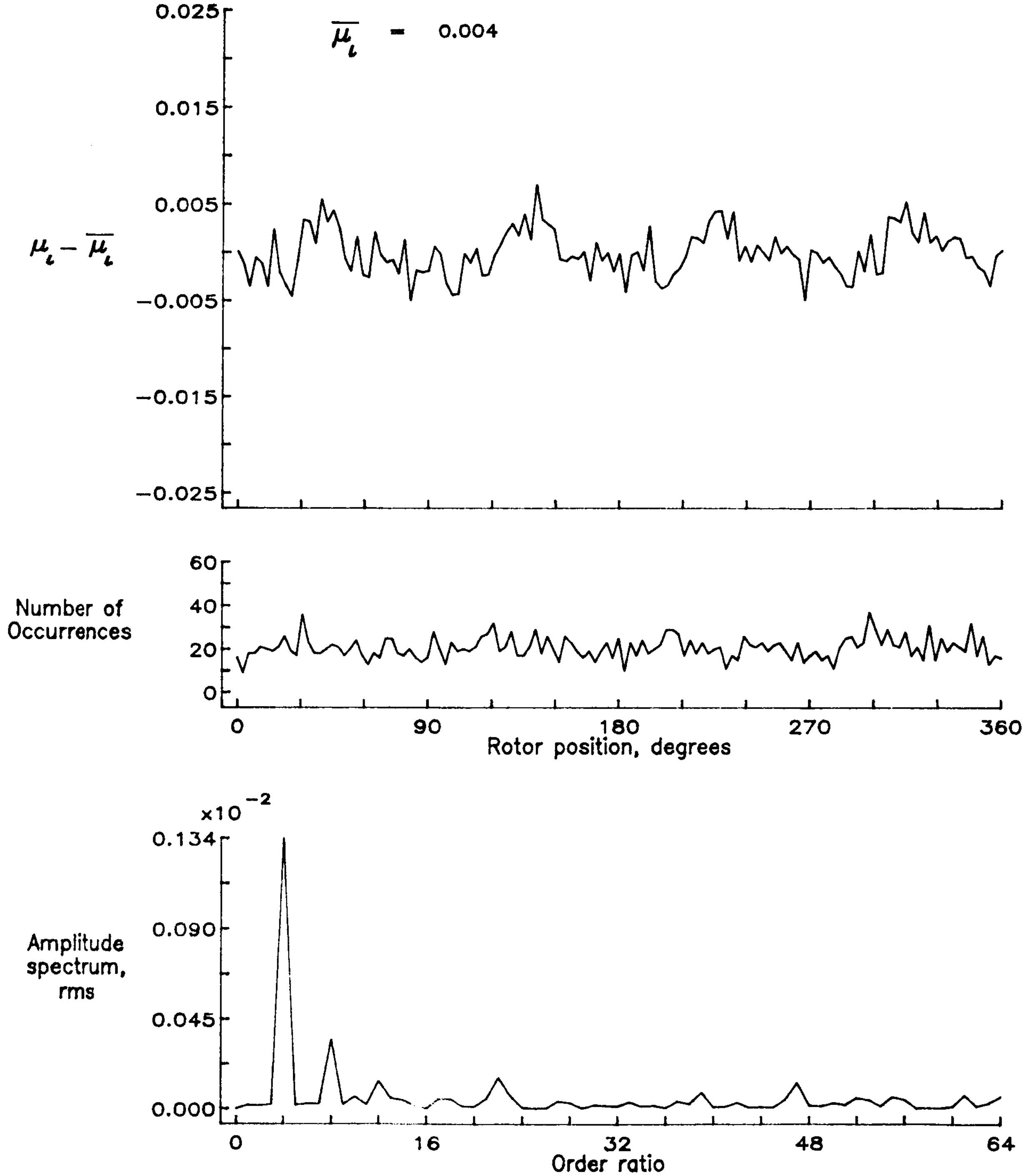
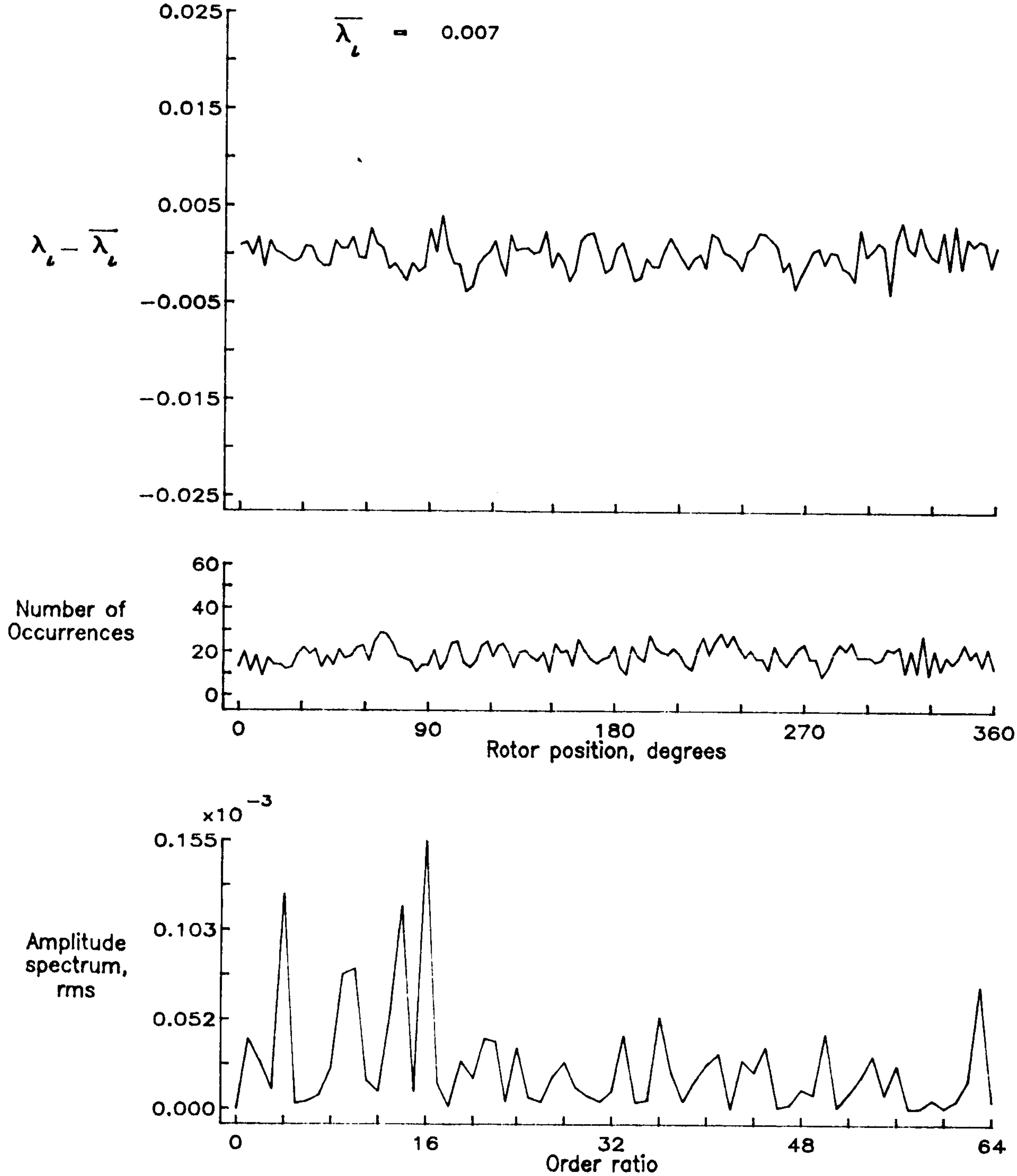


Figure 131.— Induced inflow velocity measured at 210 degrees and r/R of 1.04.



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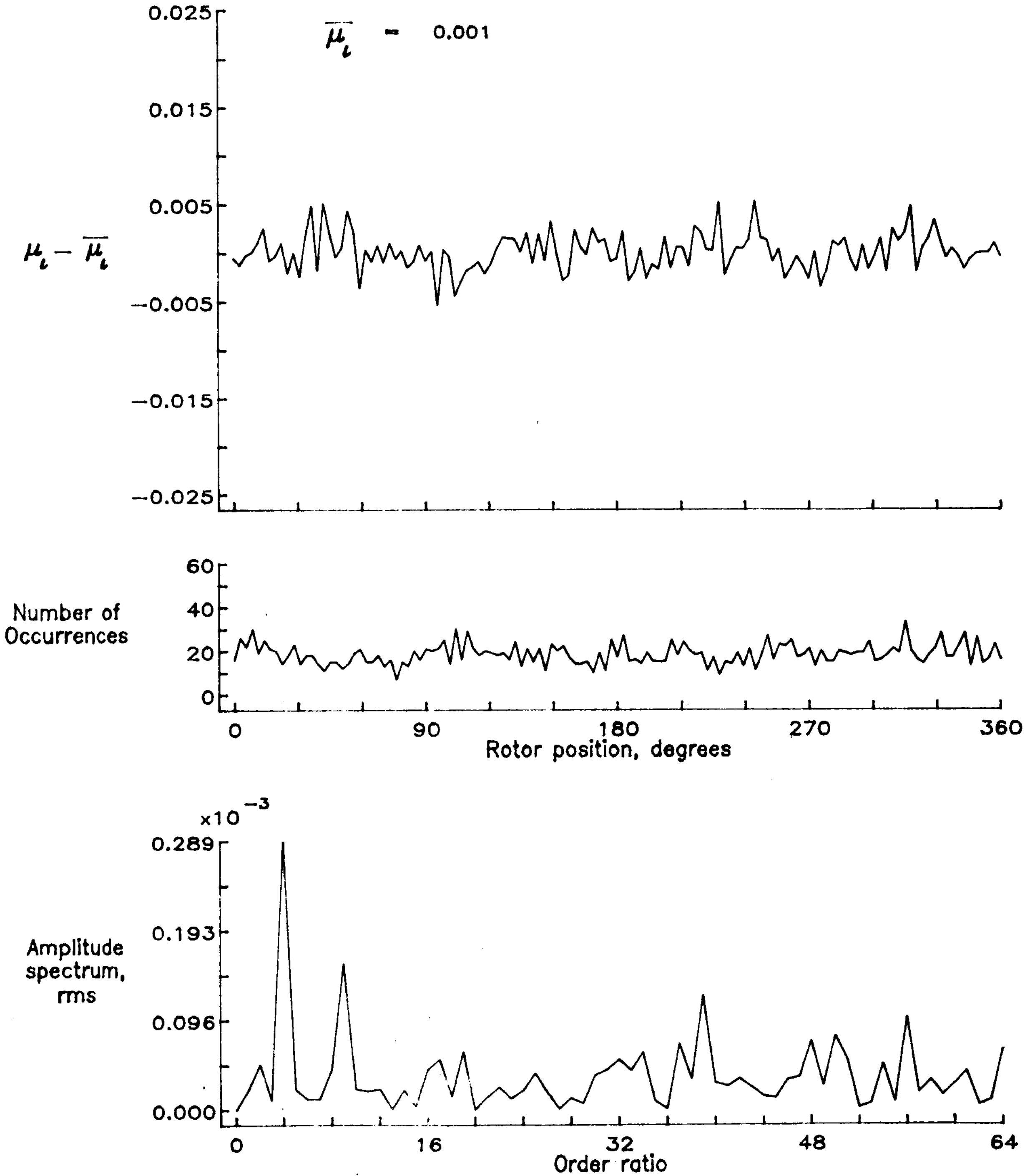
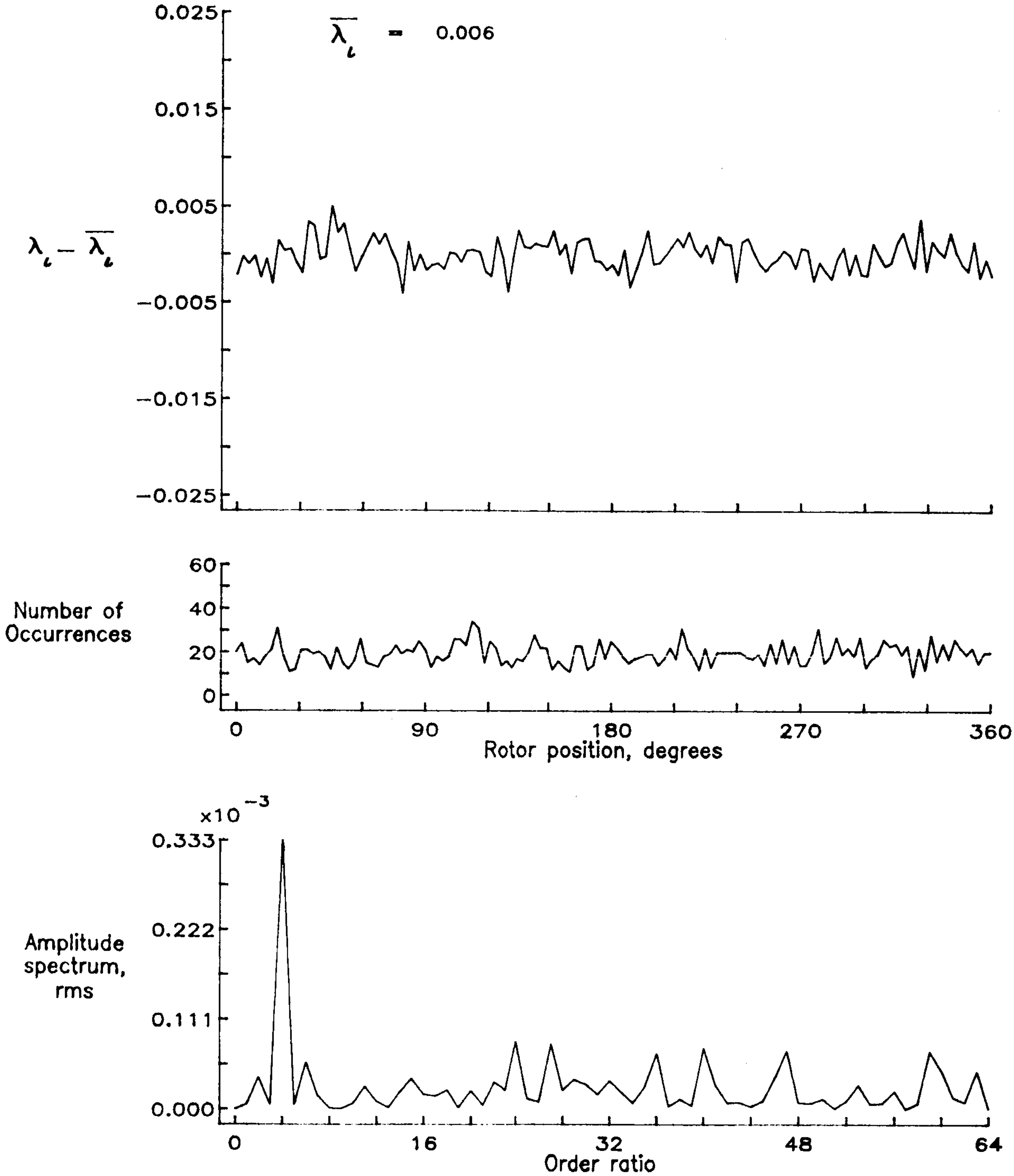


Figure 132.– Induced inflow velocity measured at 210 degrees and r/R of 1.10.



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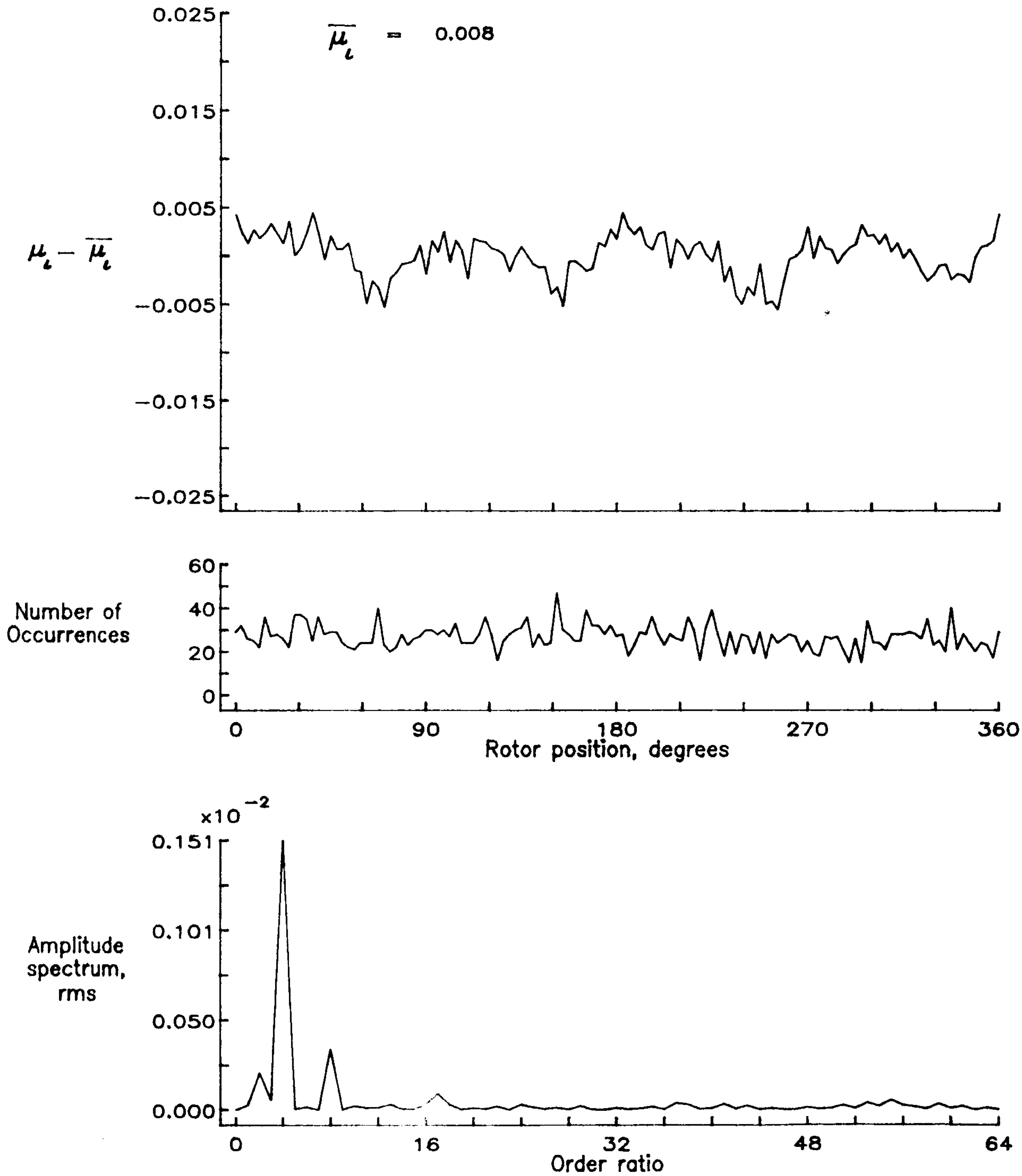
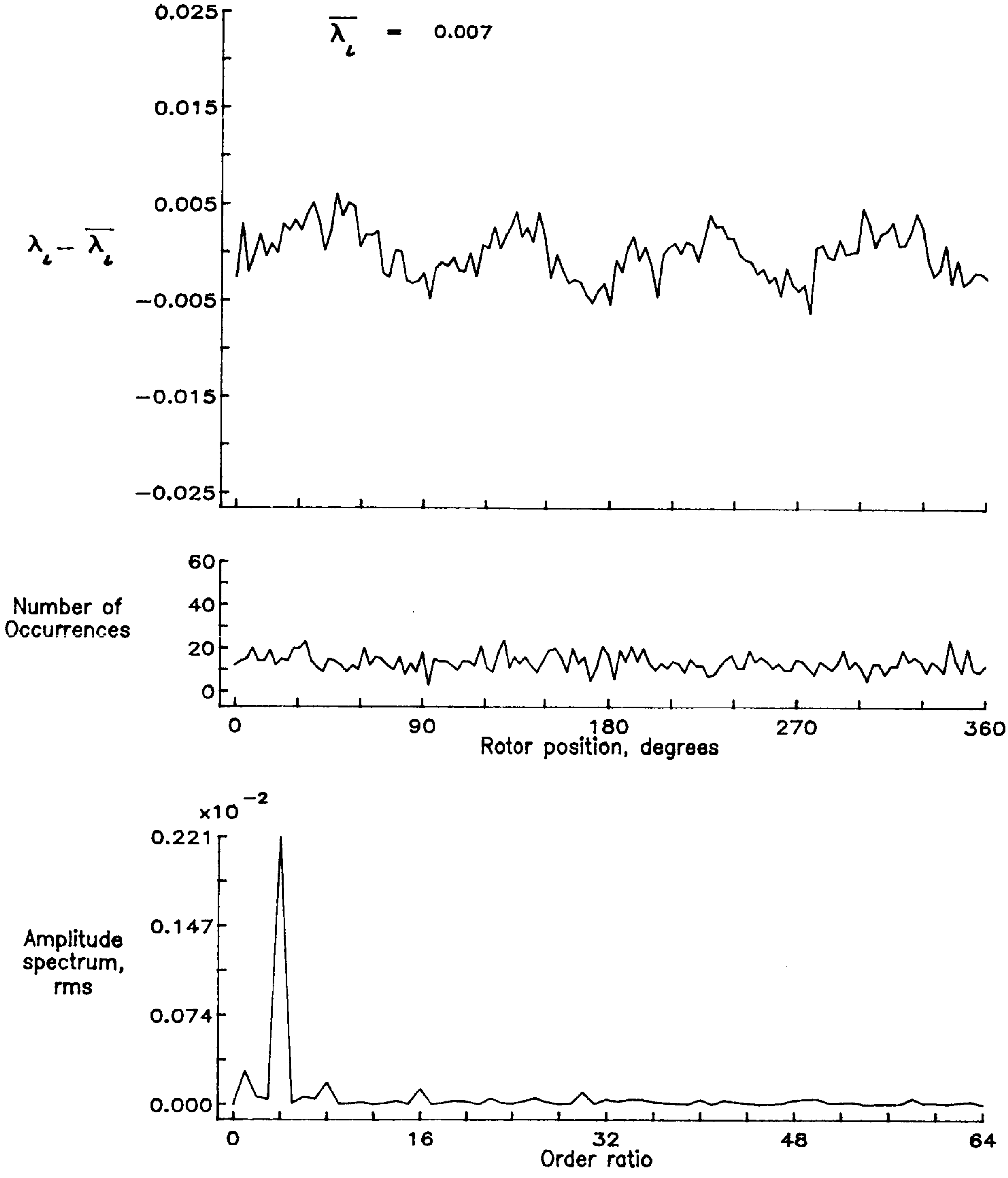


Figure 133.– Induced inflow velocity measured at 240 degrees and r/R of 0.20.



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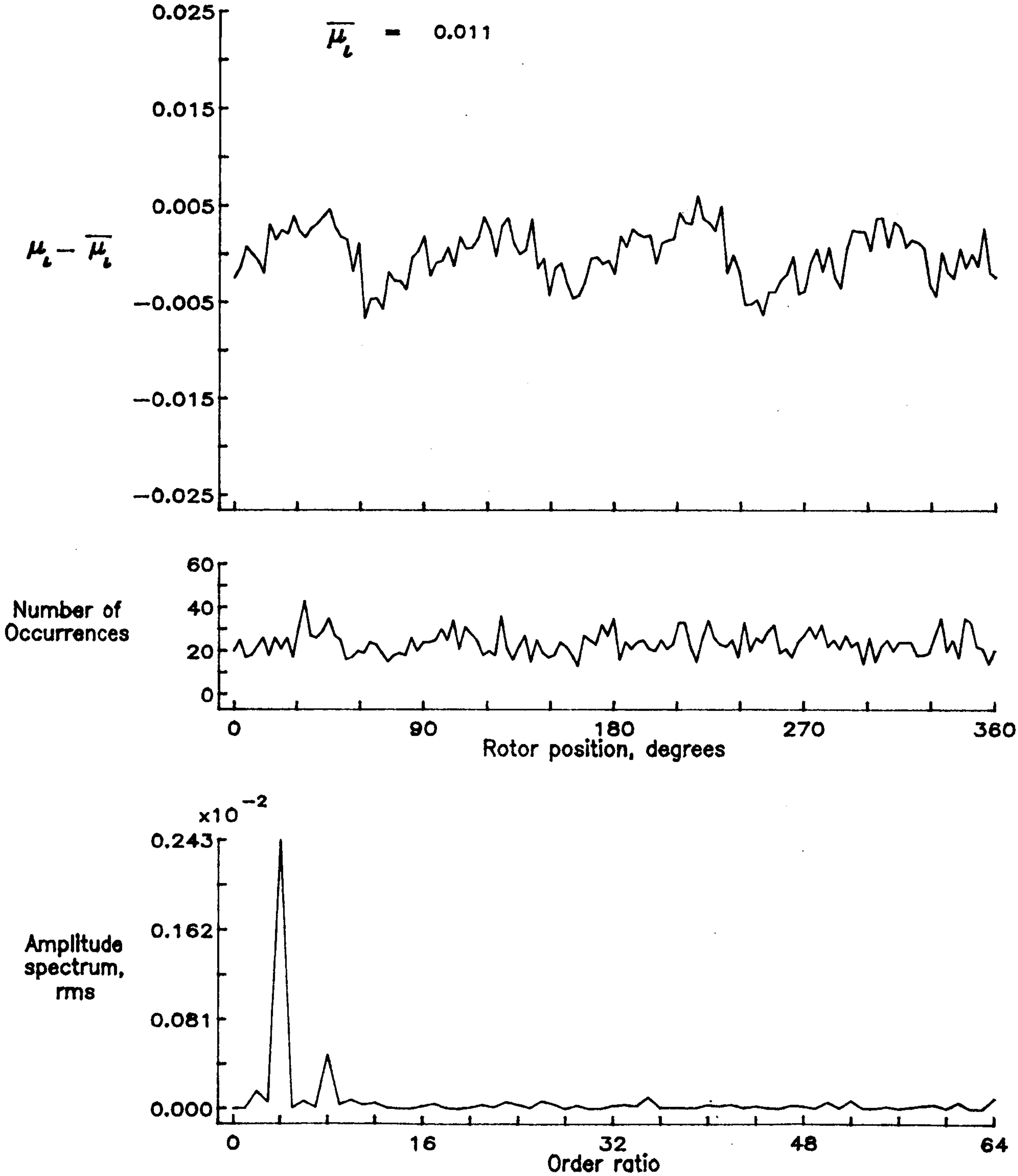
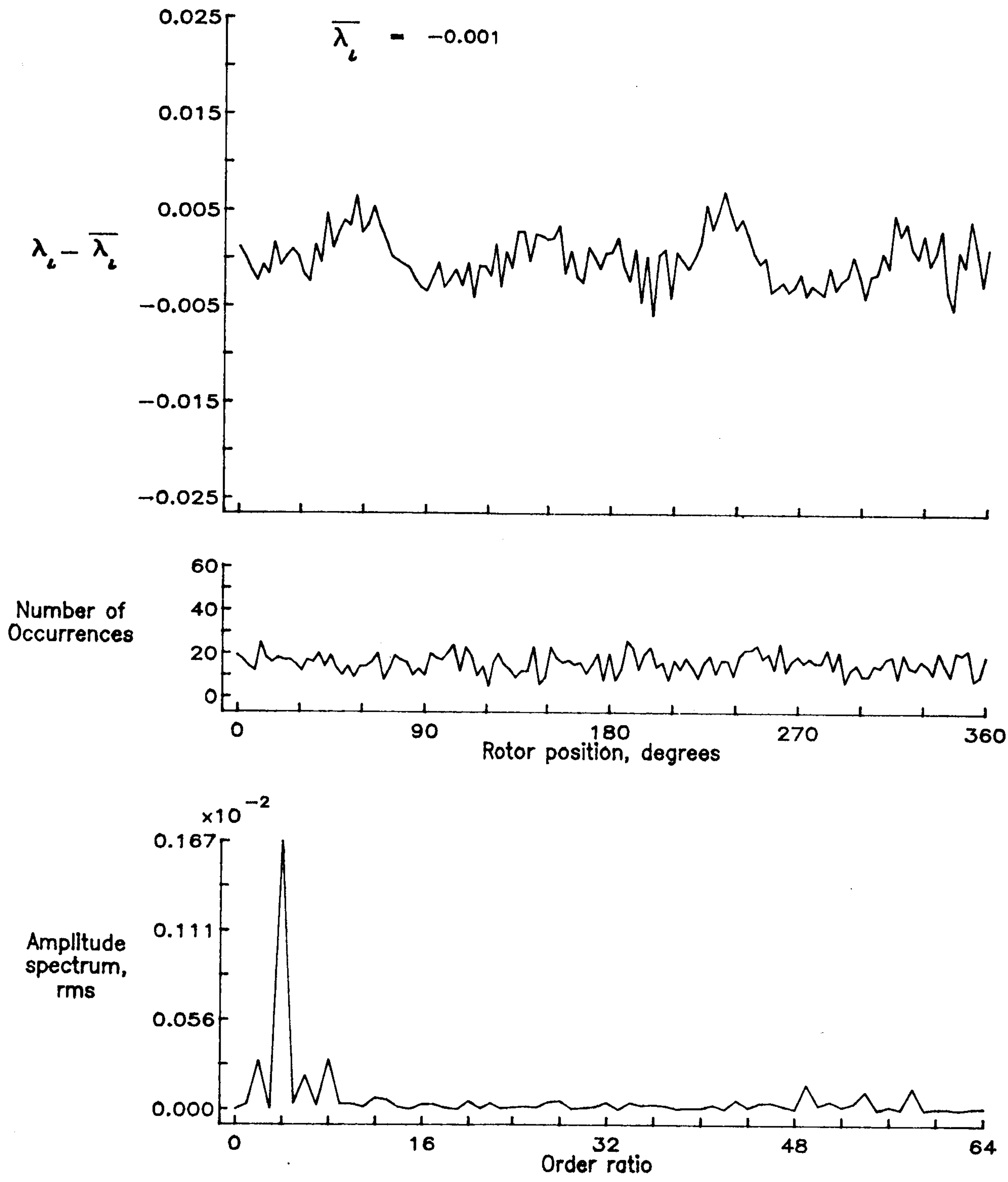


Figure 134.– Induced inflow velocity measured at 240 degrees and r/R of 0.40.



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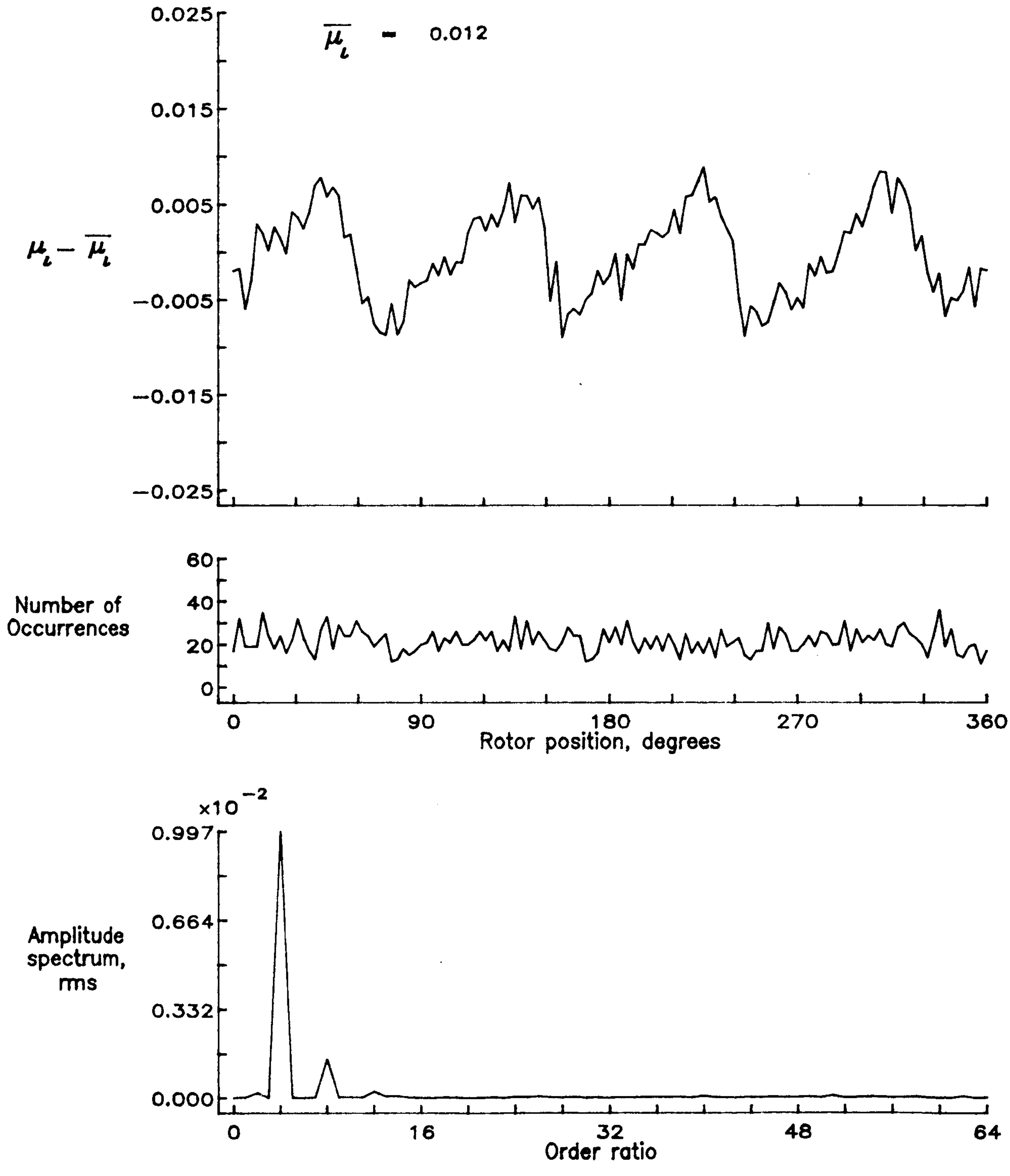
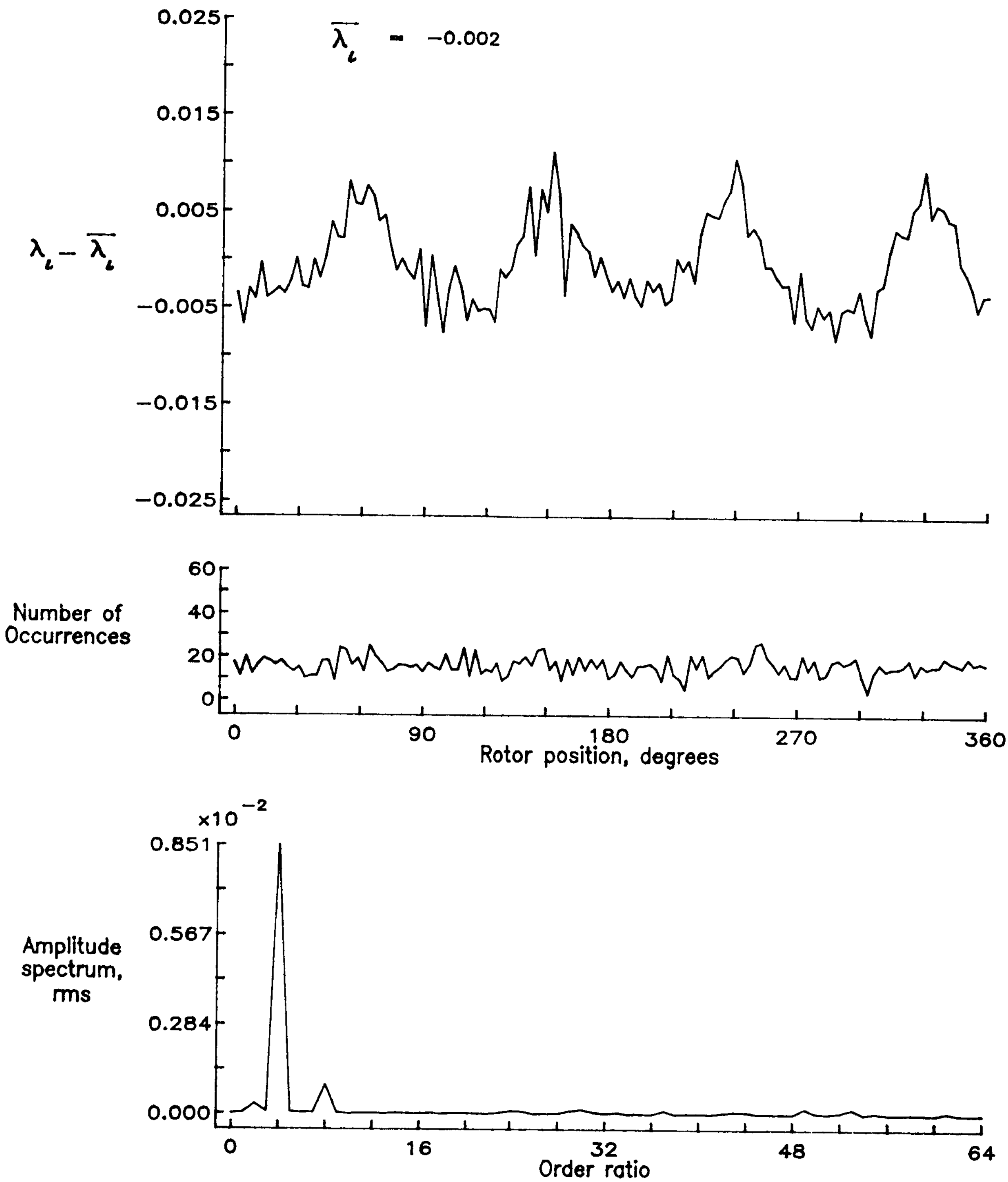


Figure 135.– Induced inflow velocity measured at 240 degrees and r/R of 0.50.



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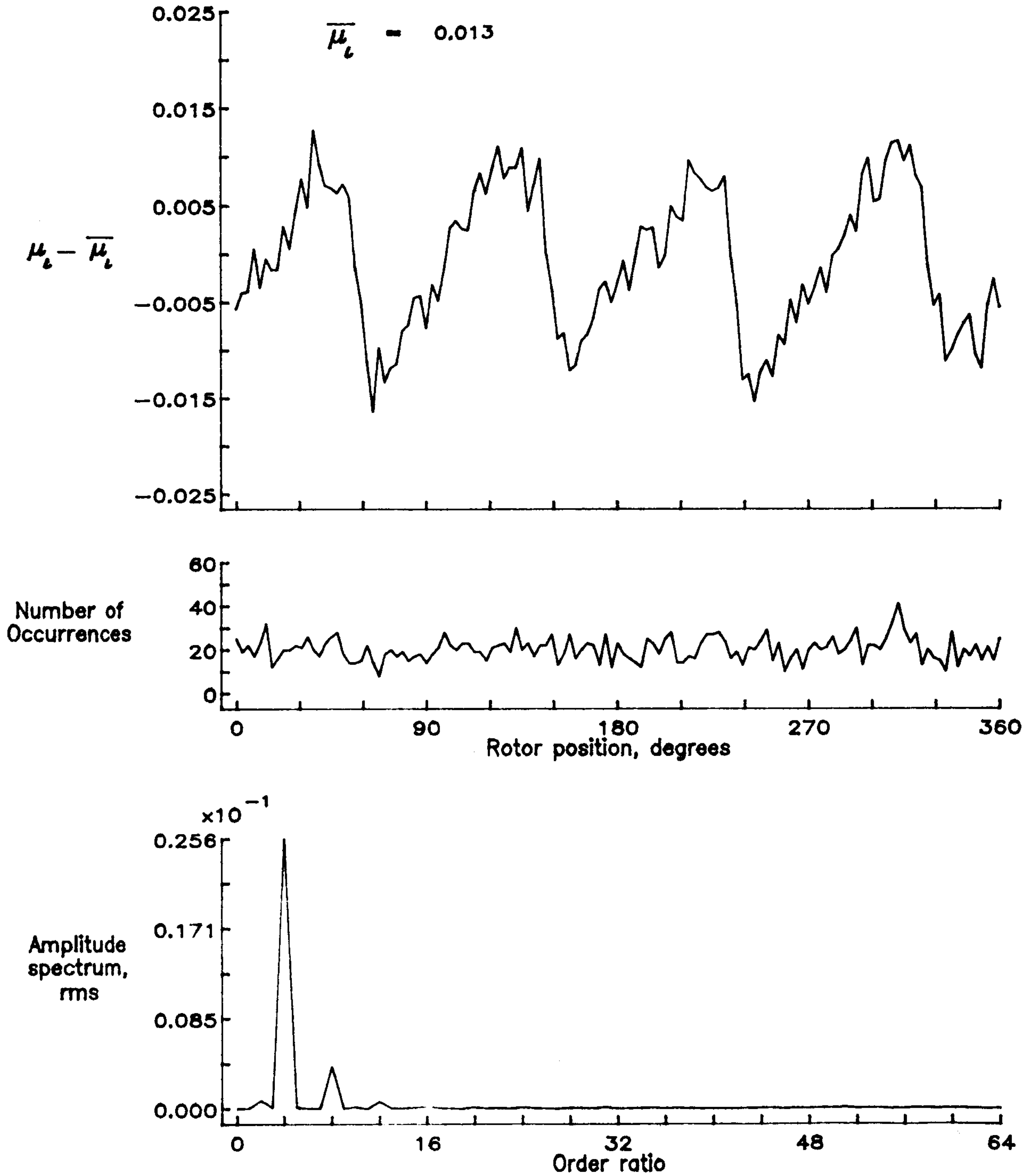
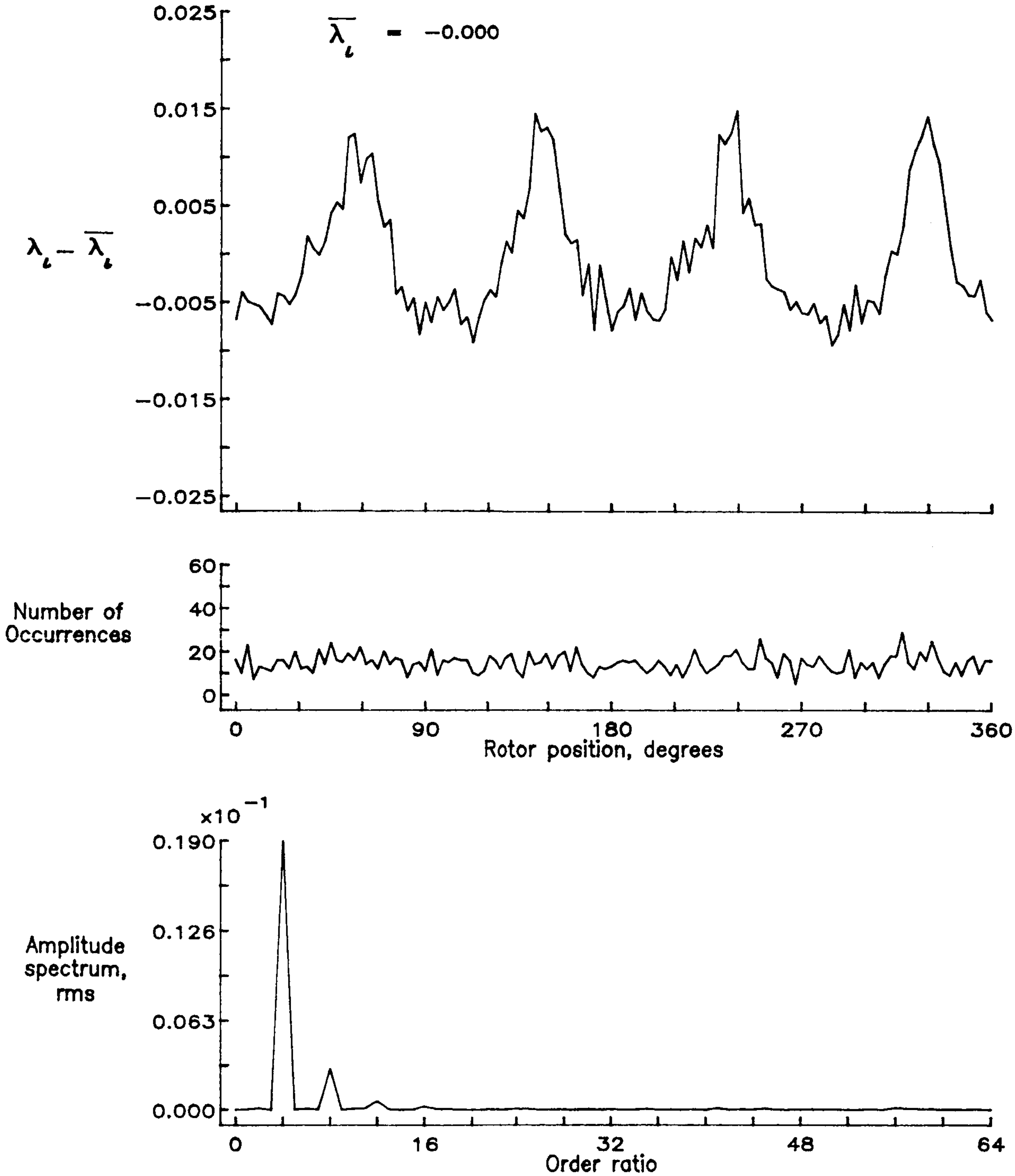


Figure 136.— Induced inflow velocity measured at 240 degrees and r/R of 0.60.



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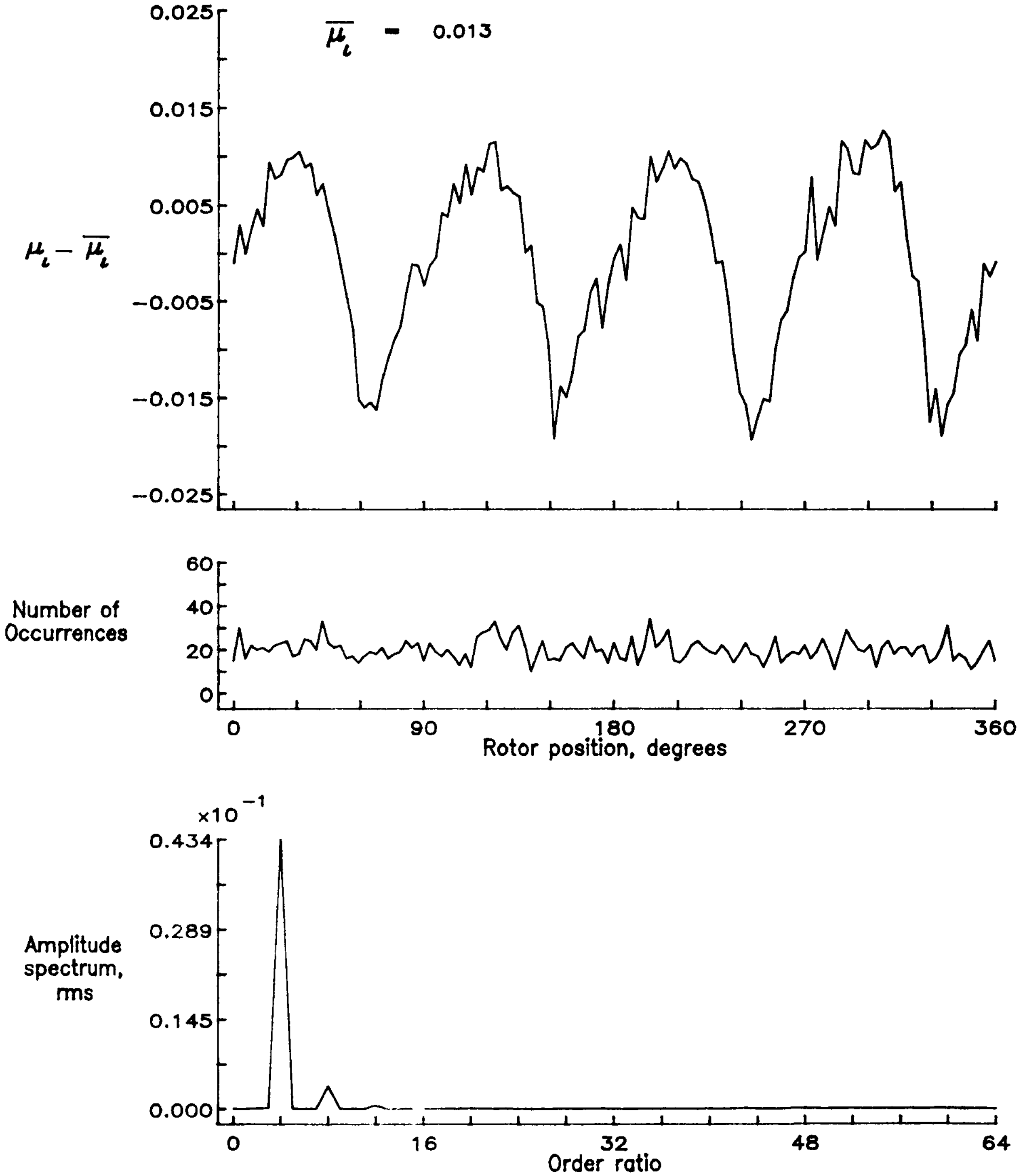
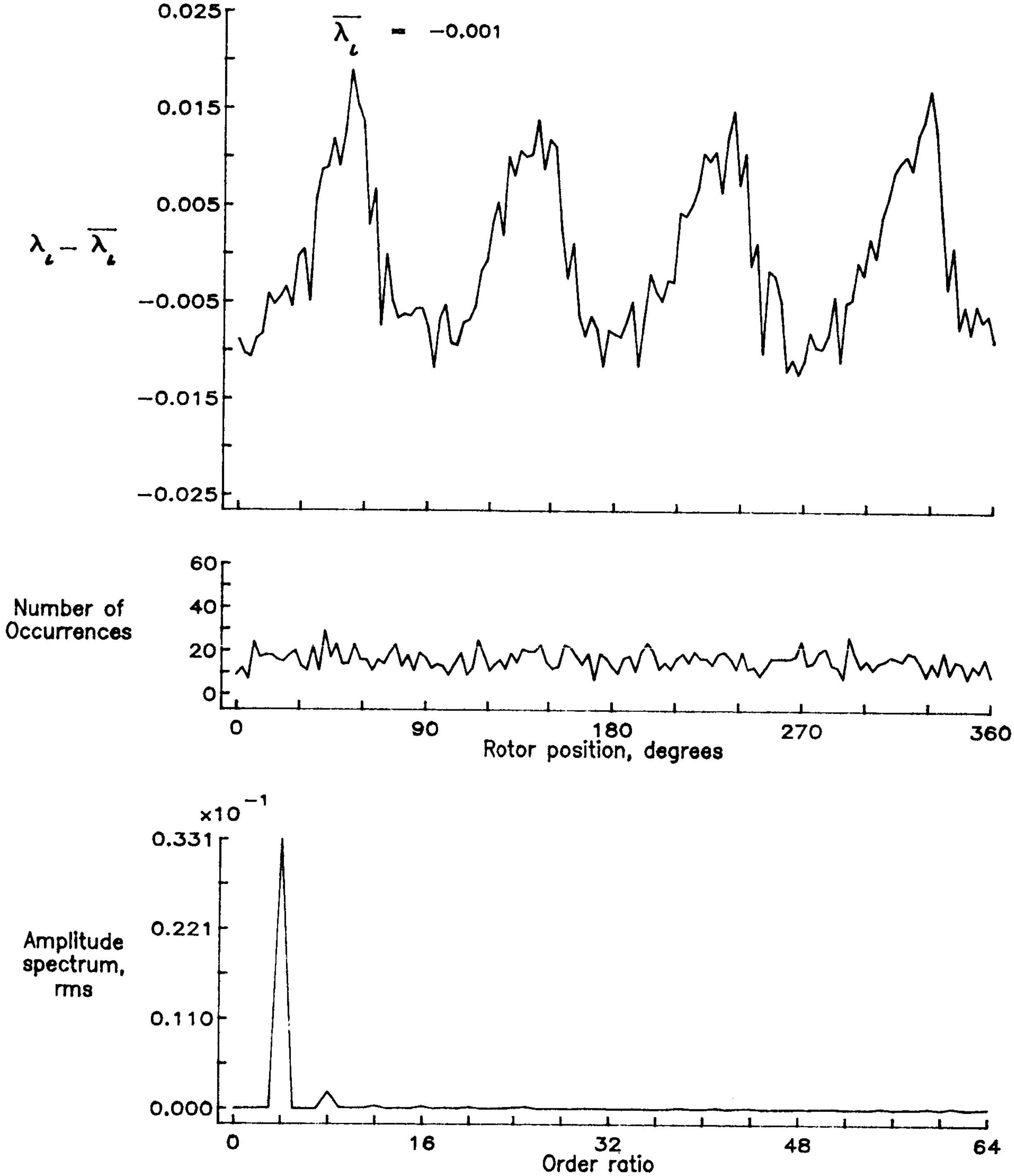


Figure 137.— Induced inflow velocity measured at 240 degrees and r/R of 0.70.



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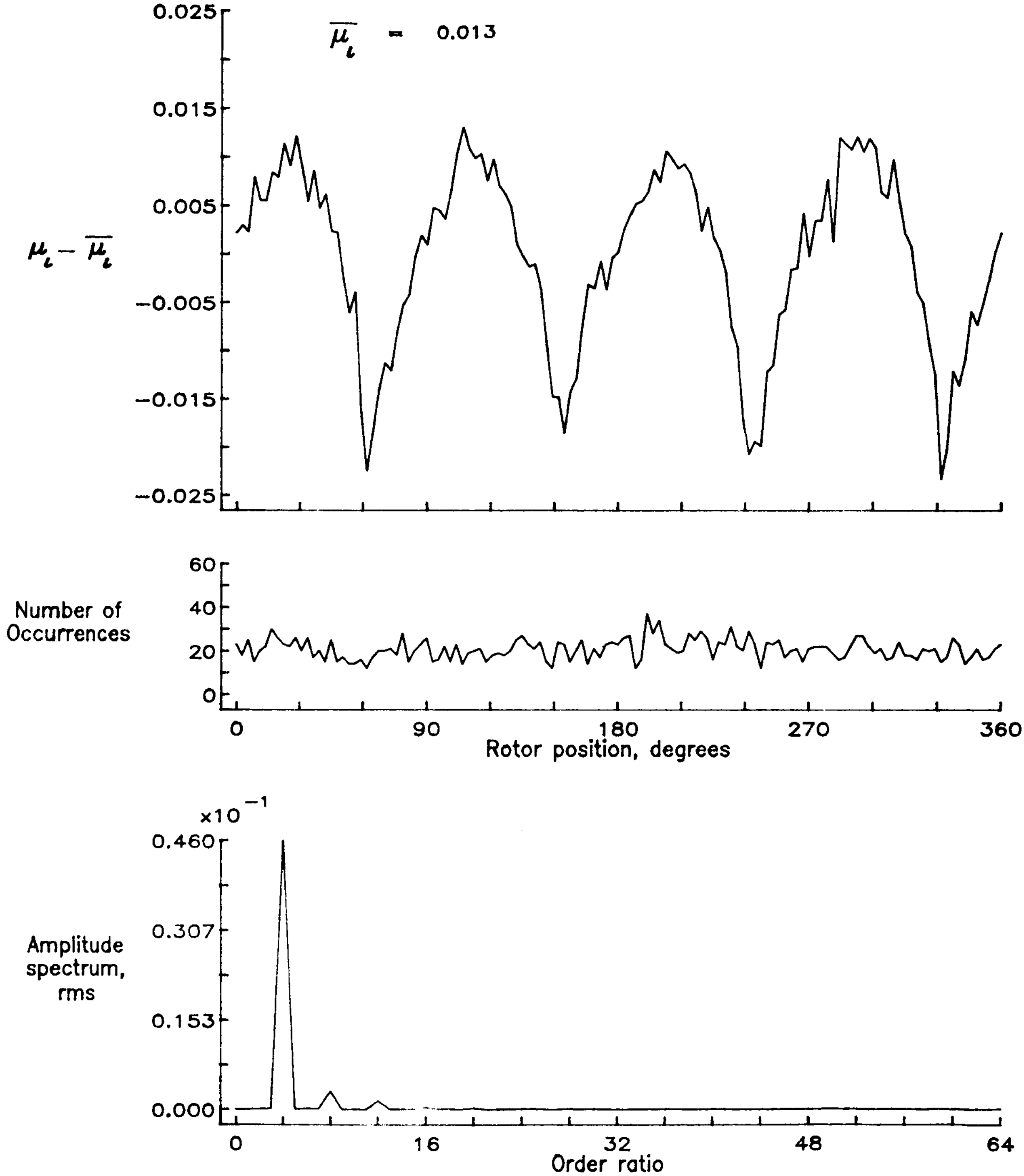
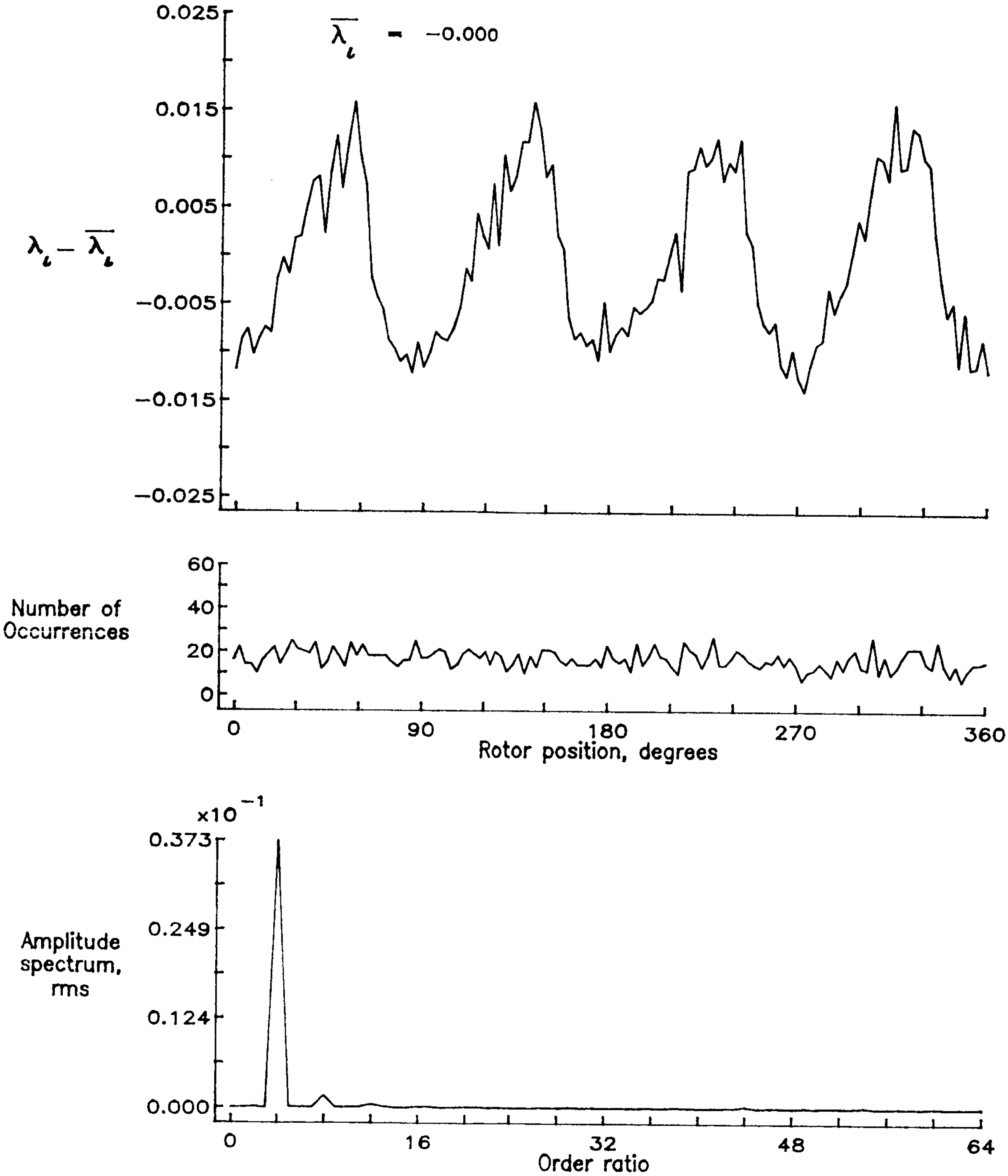


Figure 138.— Induced inflow velocity measured at 240 degrees and r/R of 0.74.



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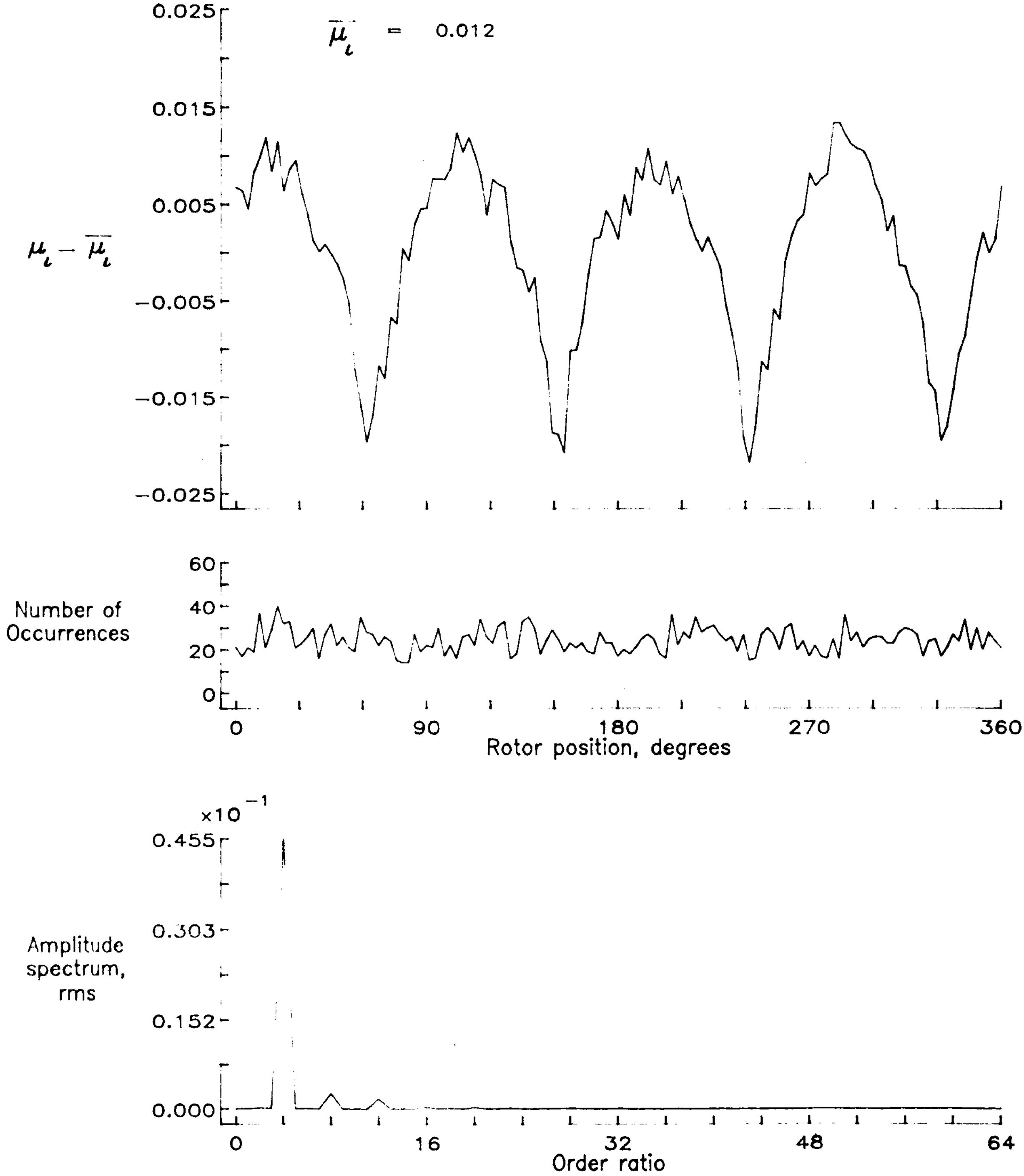

Figure 139.— Induced inflow velocity measured at 240 degrees and r/R of 0.78.

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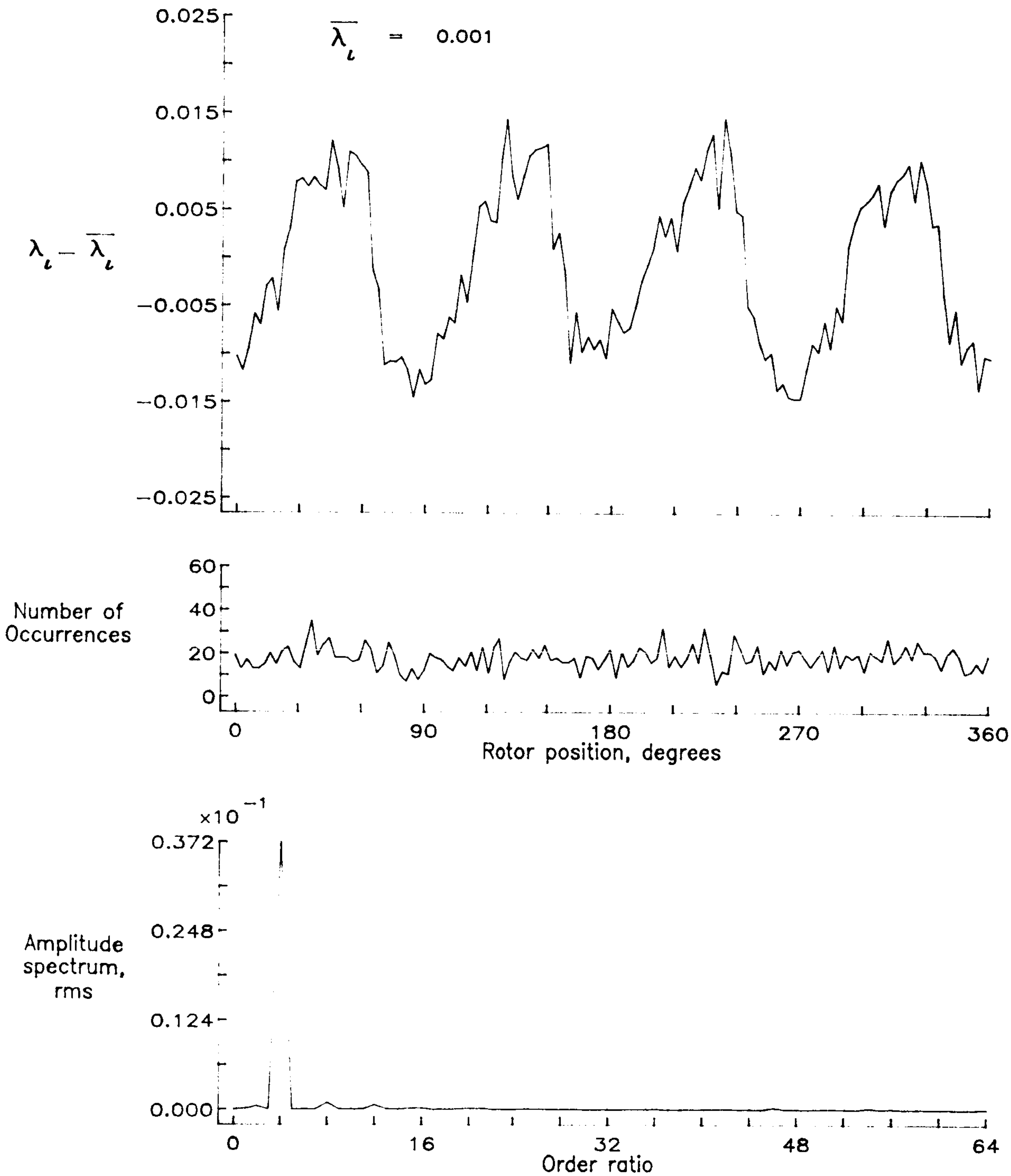

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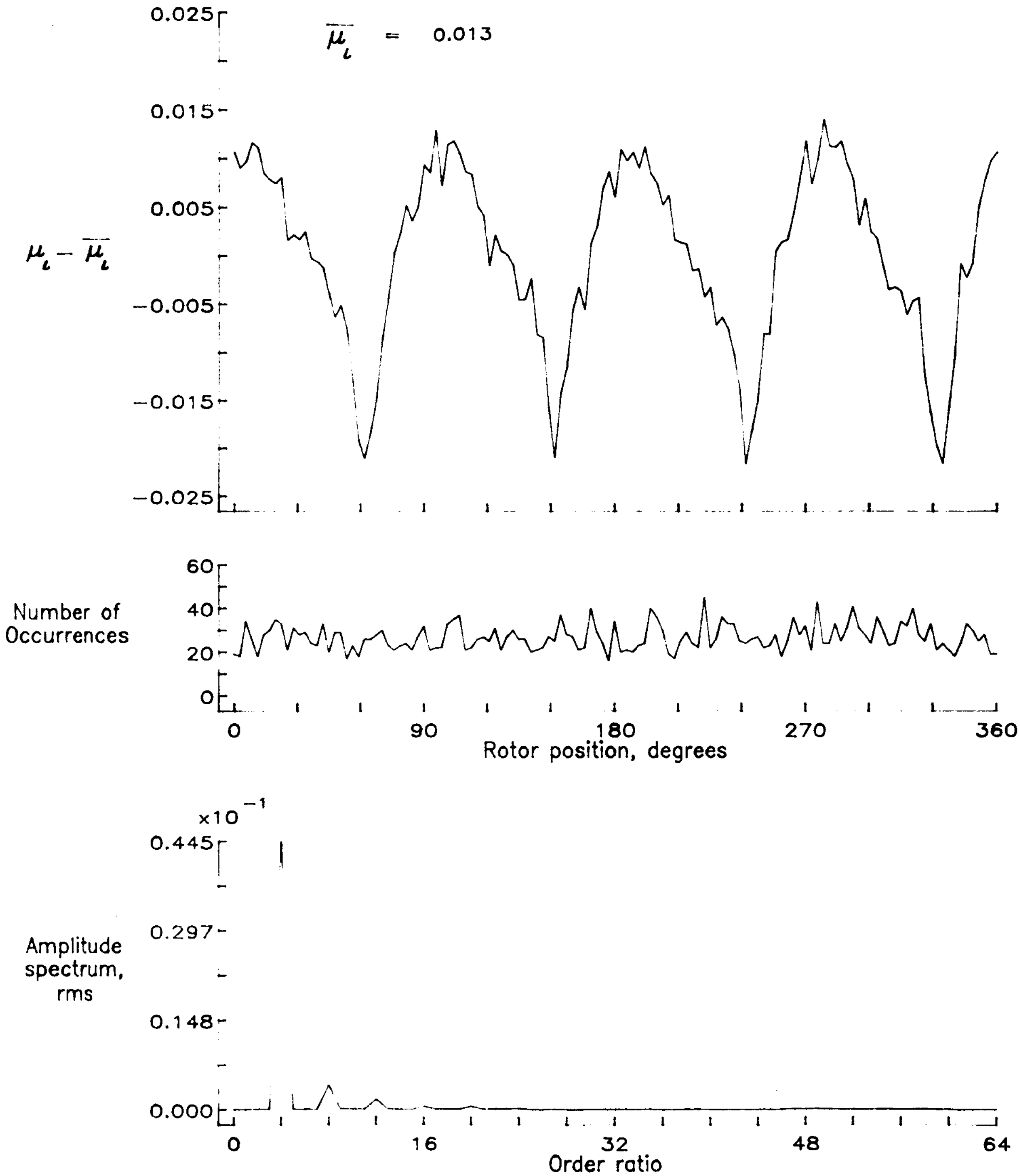

Figure 140.– Induced inflow velocity measured at 240 degrees and r/R of 0.82.

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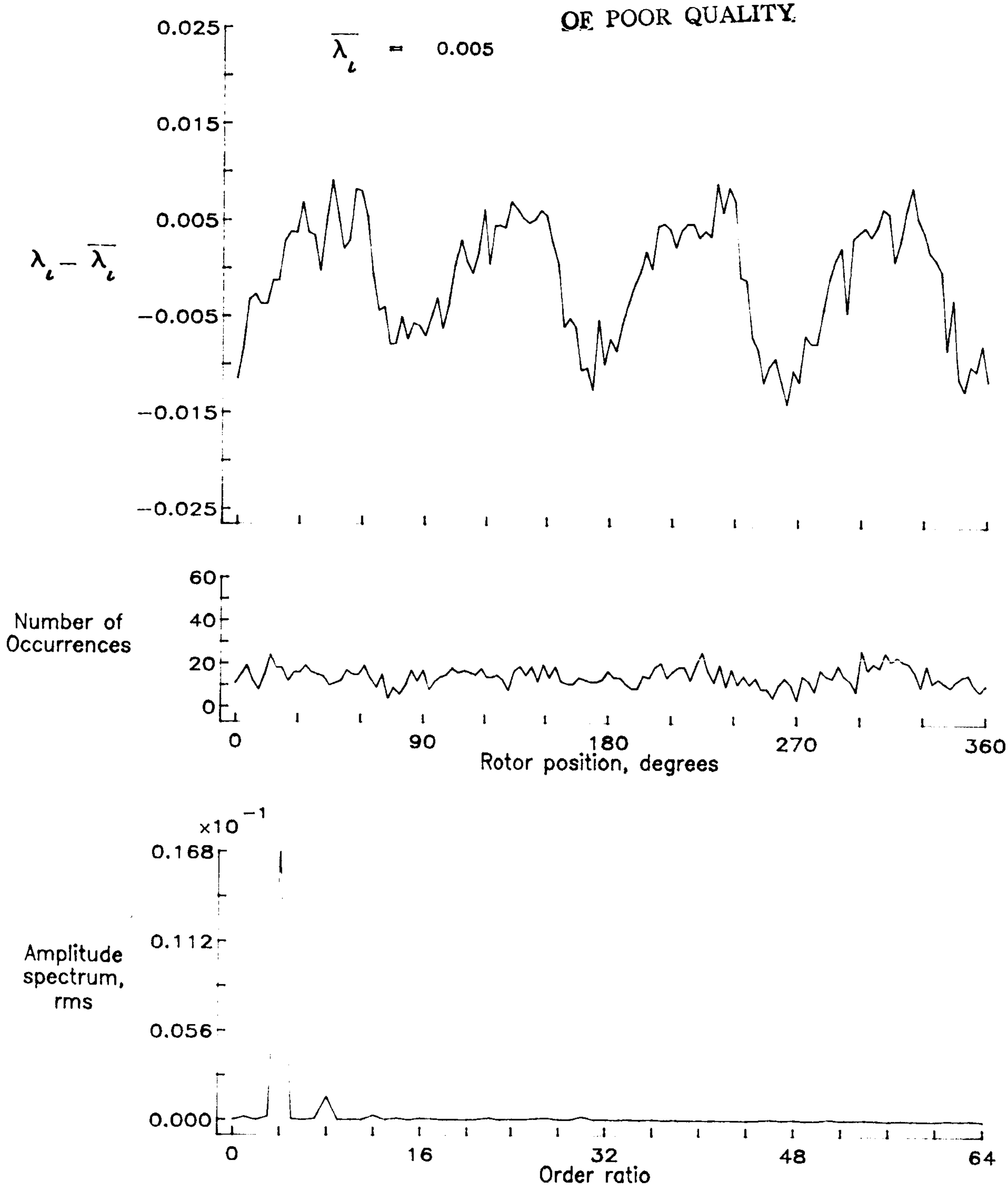

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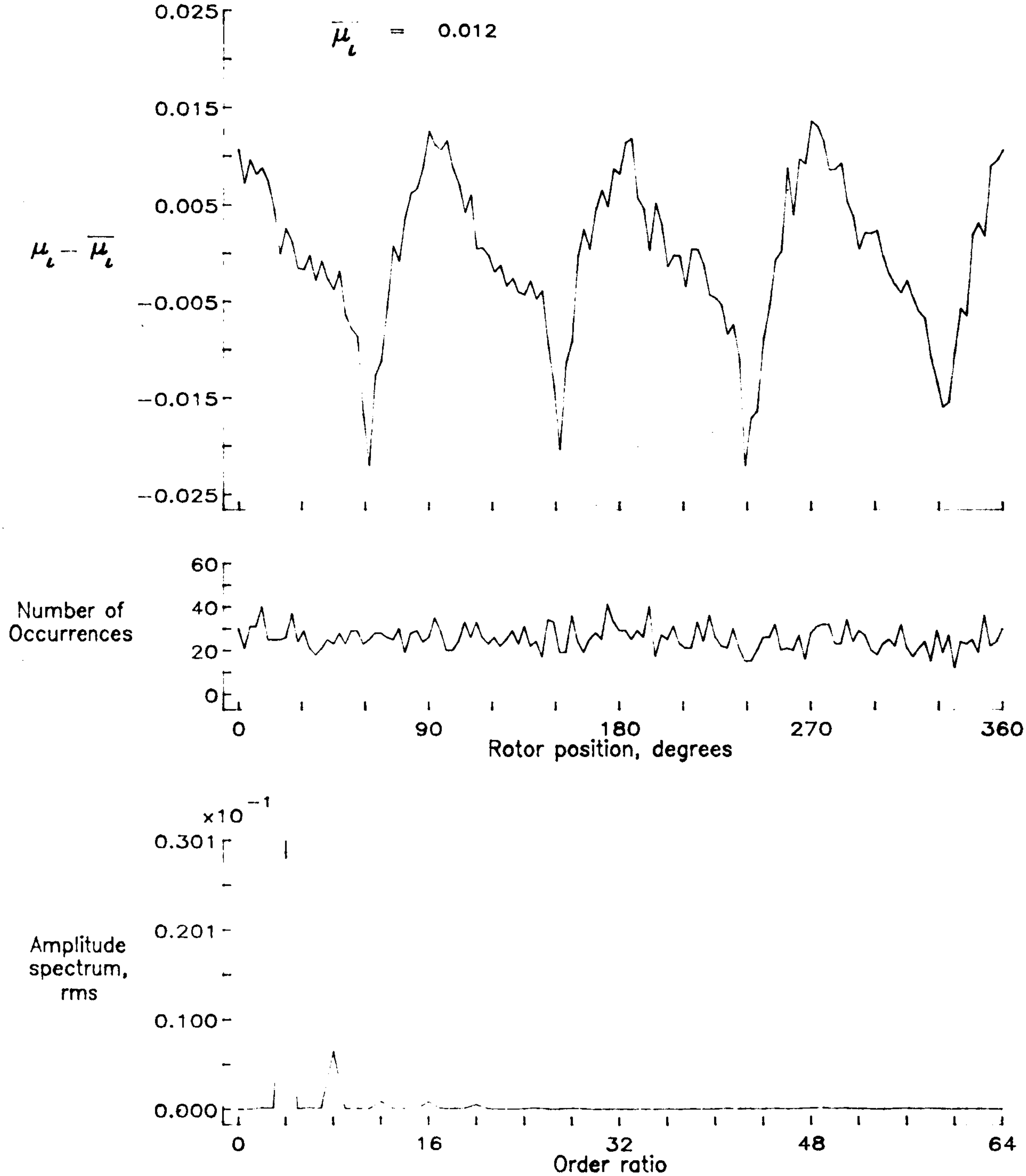
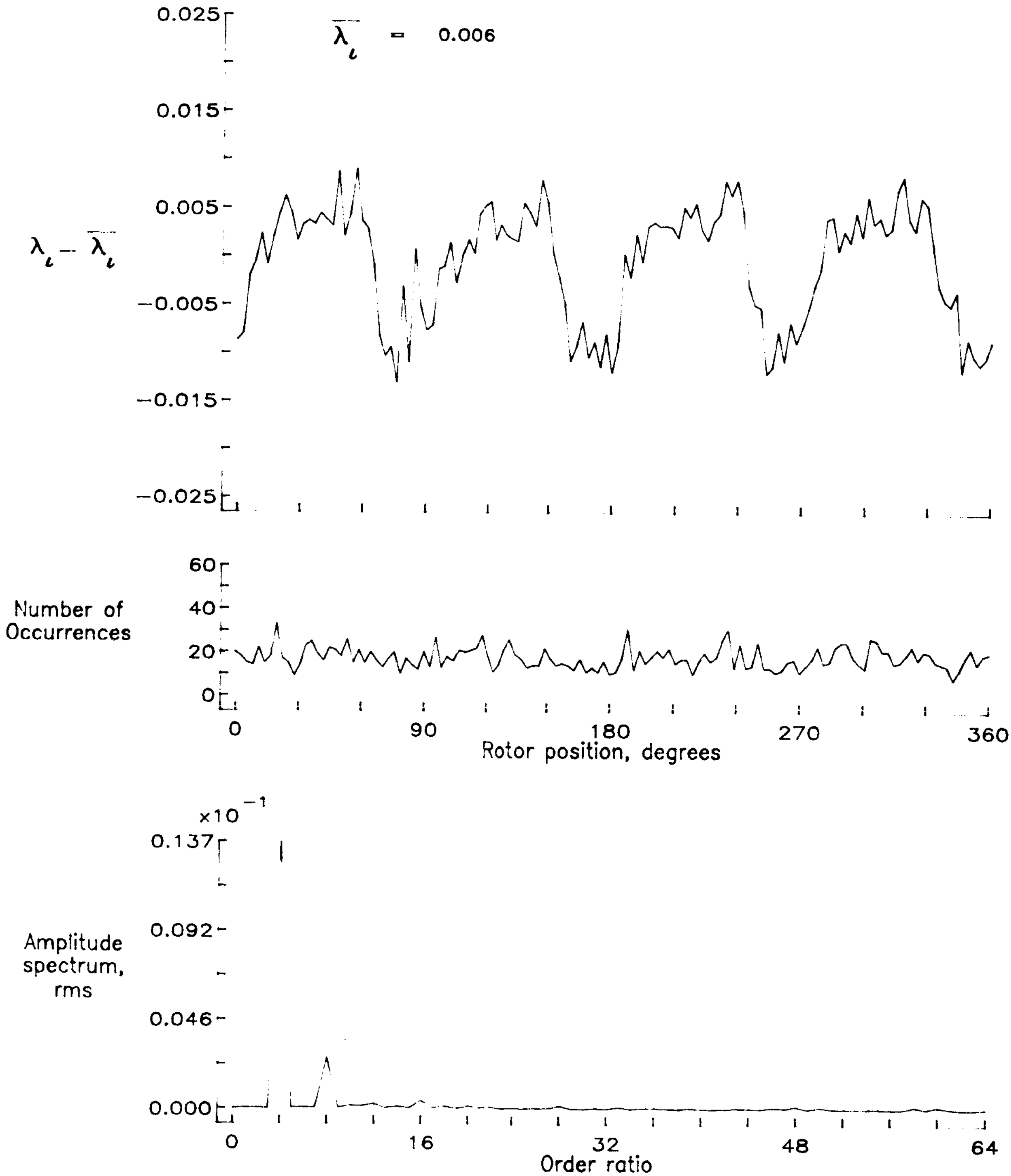


Figure 141.– Induced inflow velocity measured at 240 degrees and r/R of 0.86.



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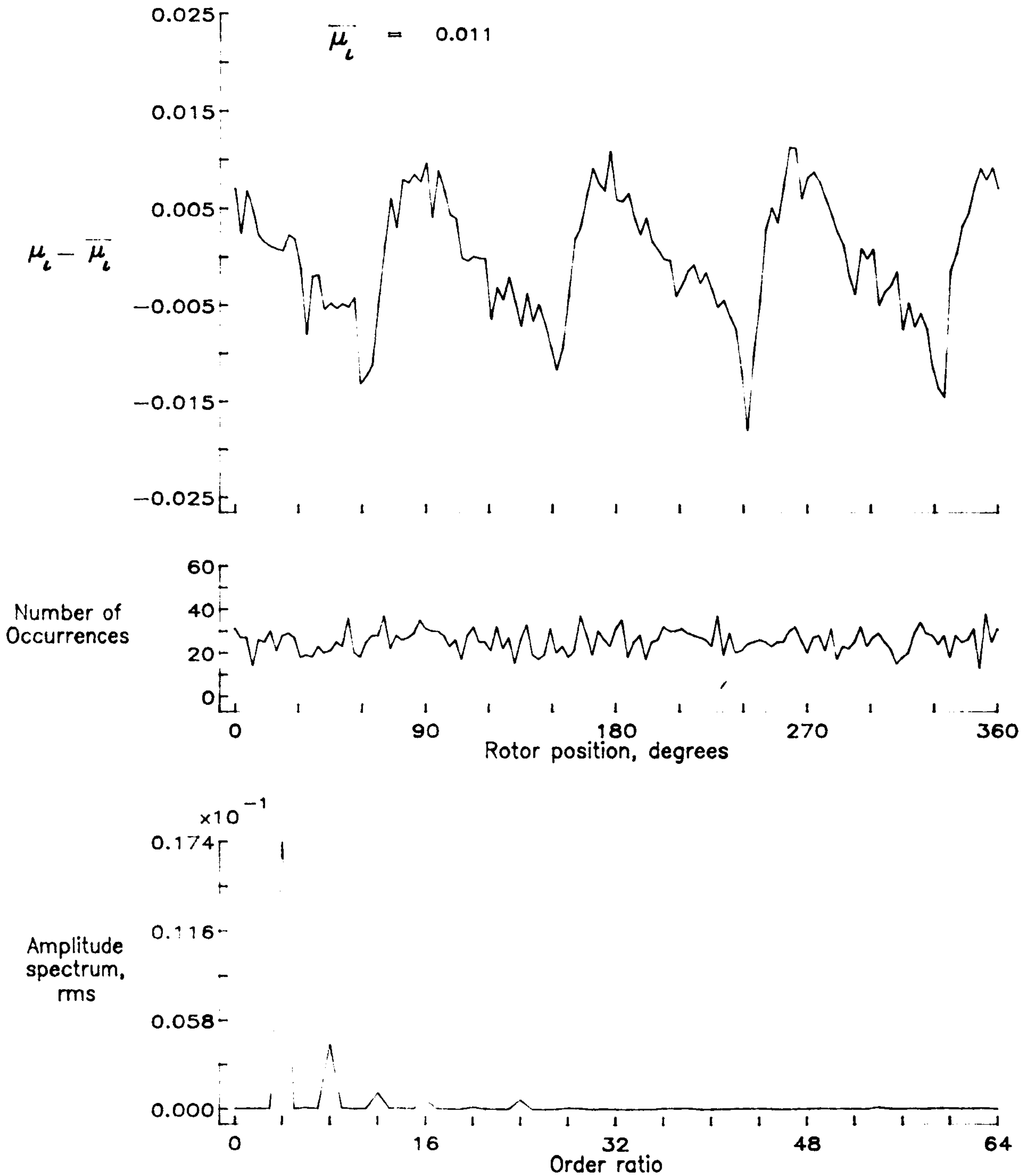
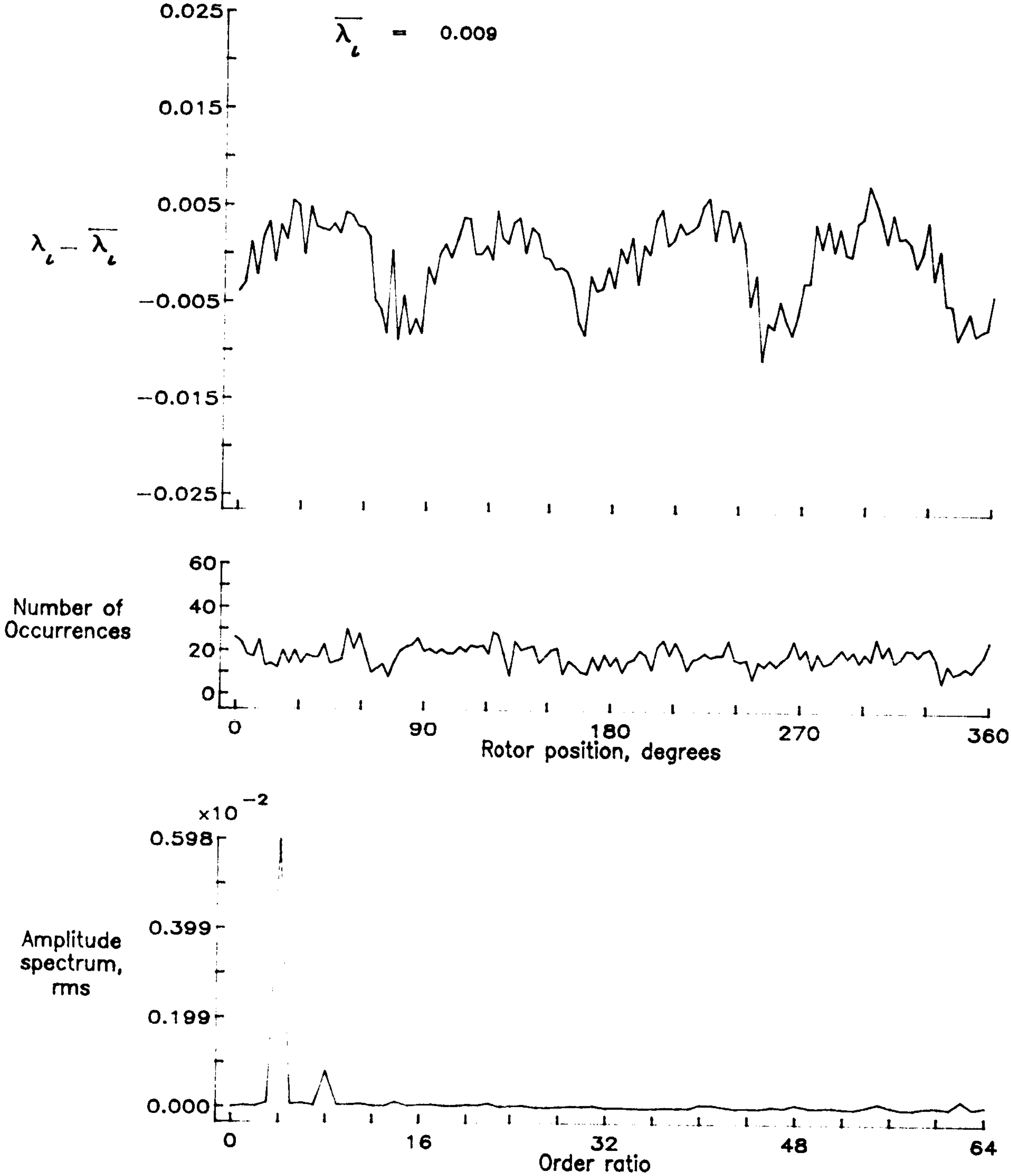


Figure 142.– Induced inflow velocity measured at 240 degrees and r/R of 0.90.



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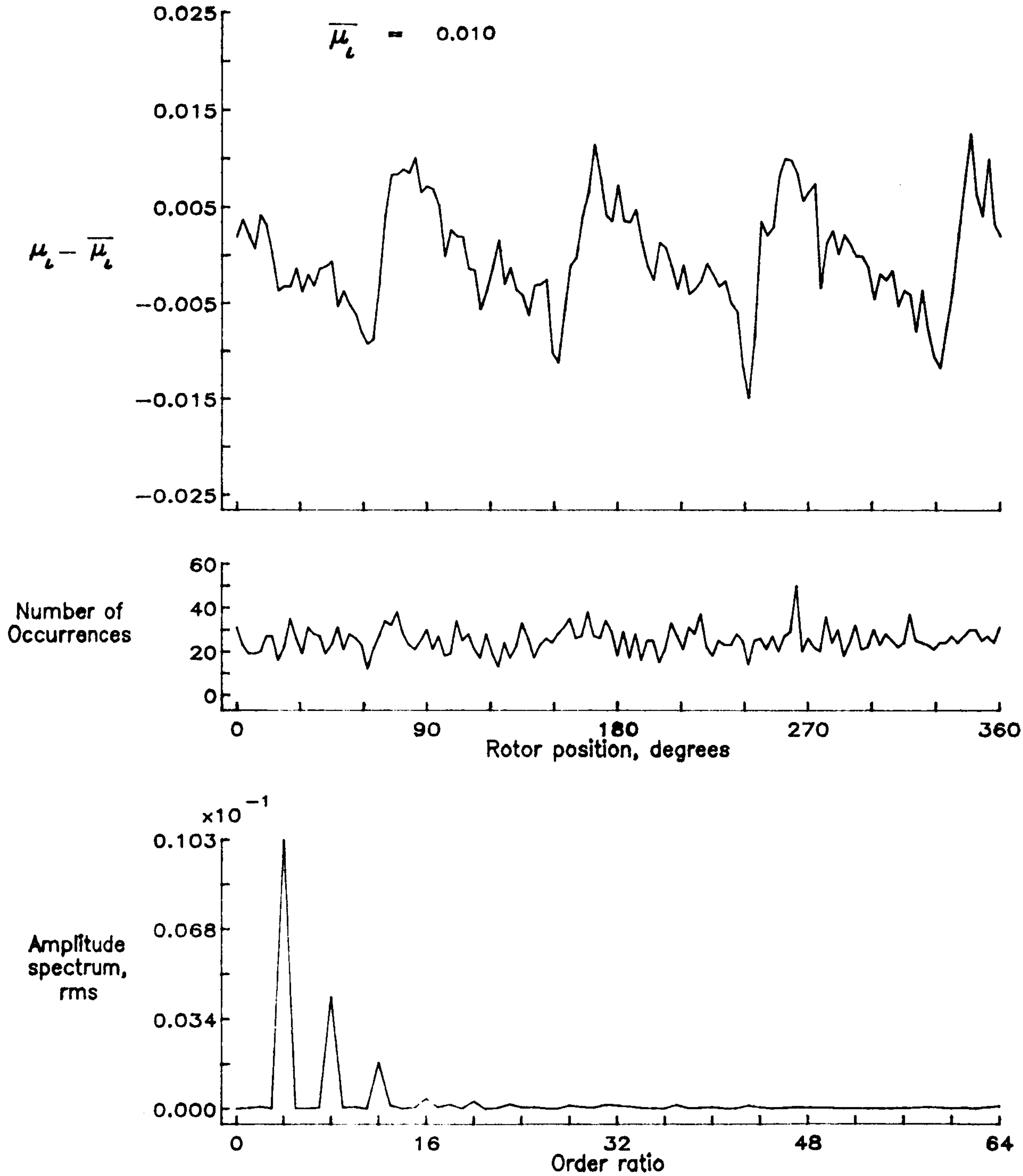
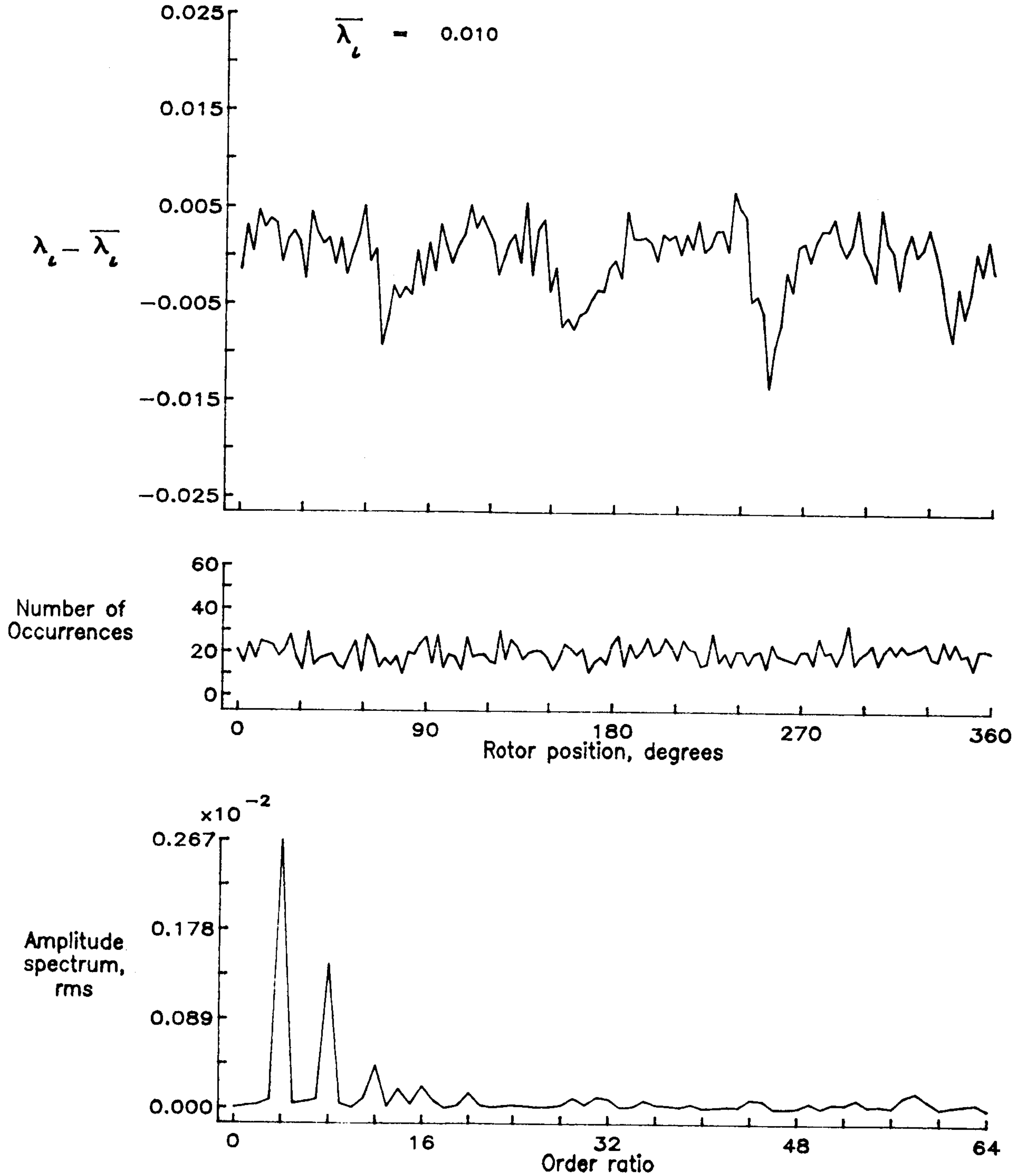


Figure 143.– Induced inflow velocity measured at 240 degrees and r/R of 0.94.



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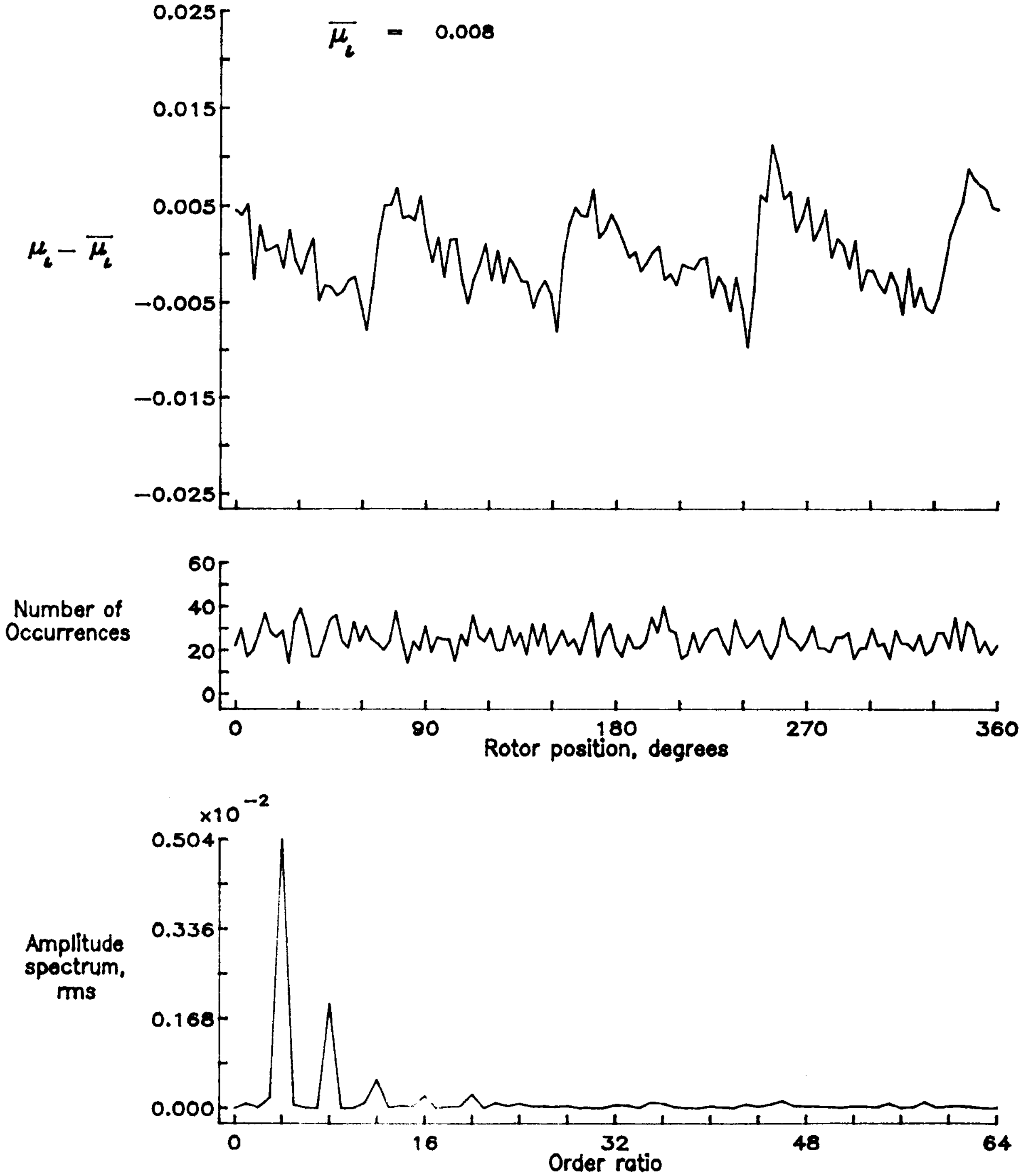

Figure 144.— Induced inflow velocity measured at 240 degrees and r/R of 0.98.

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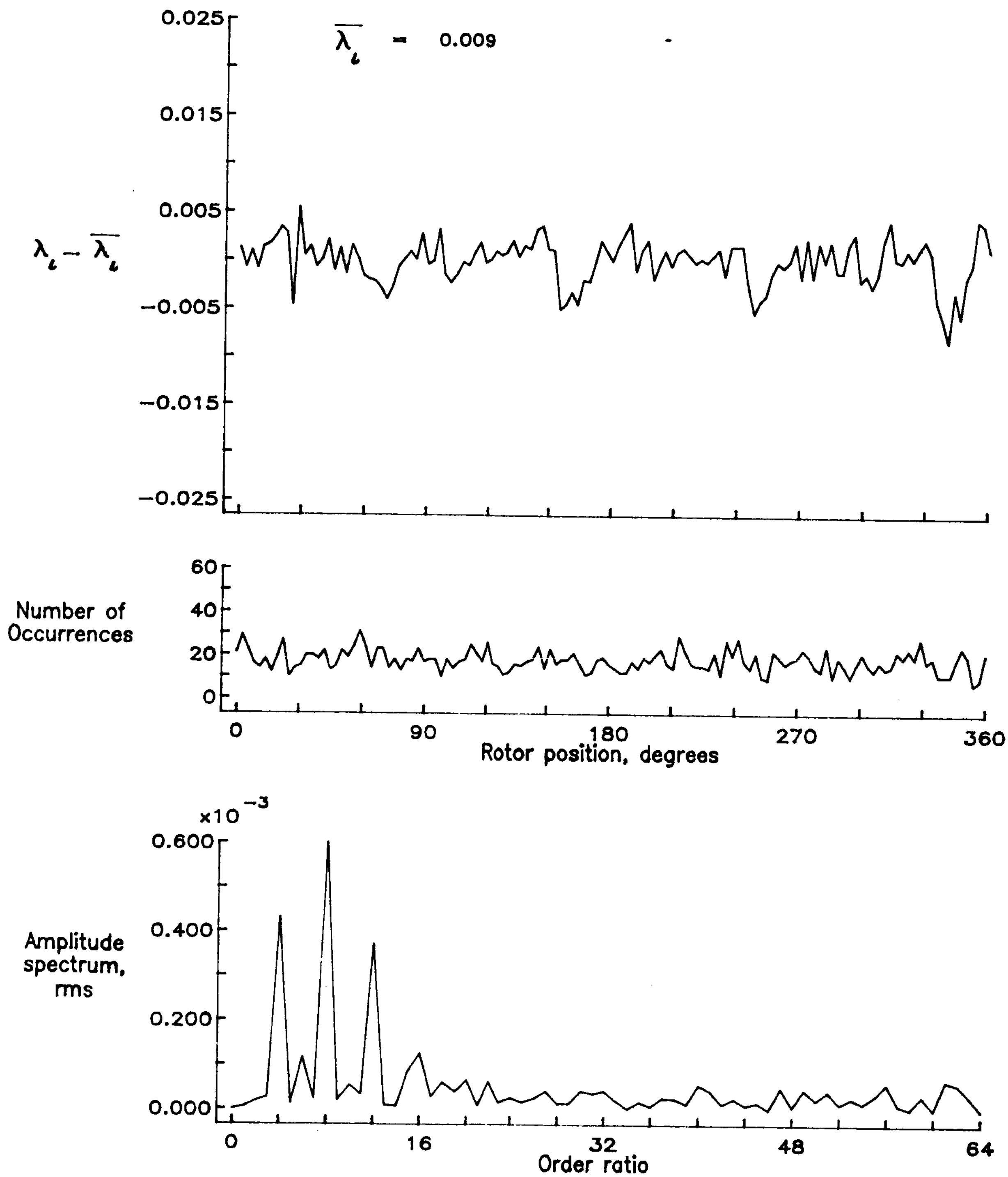

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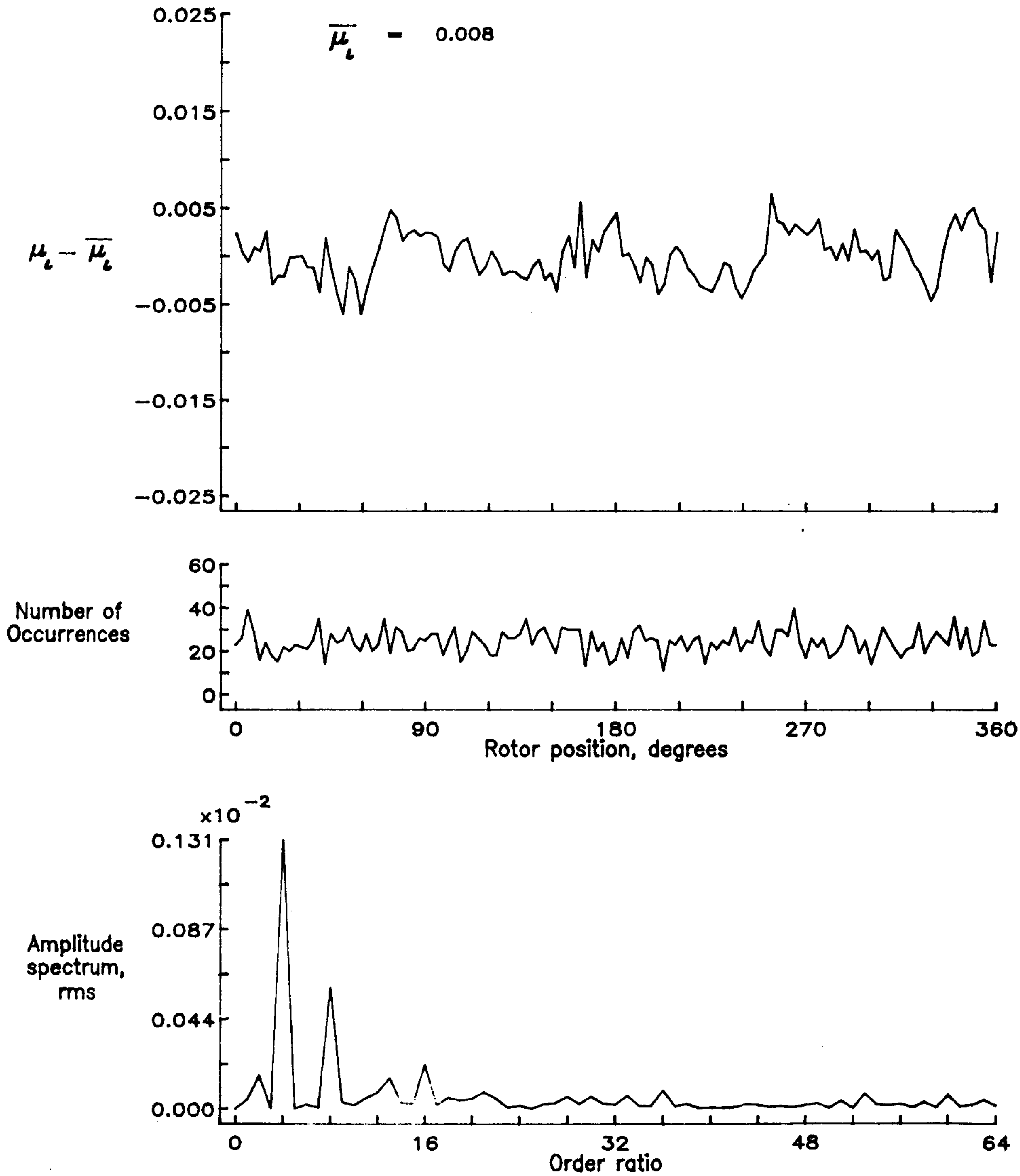
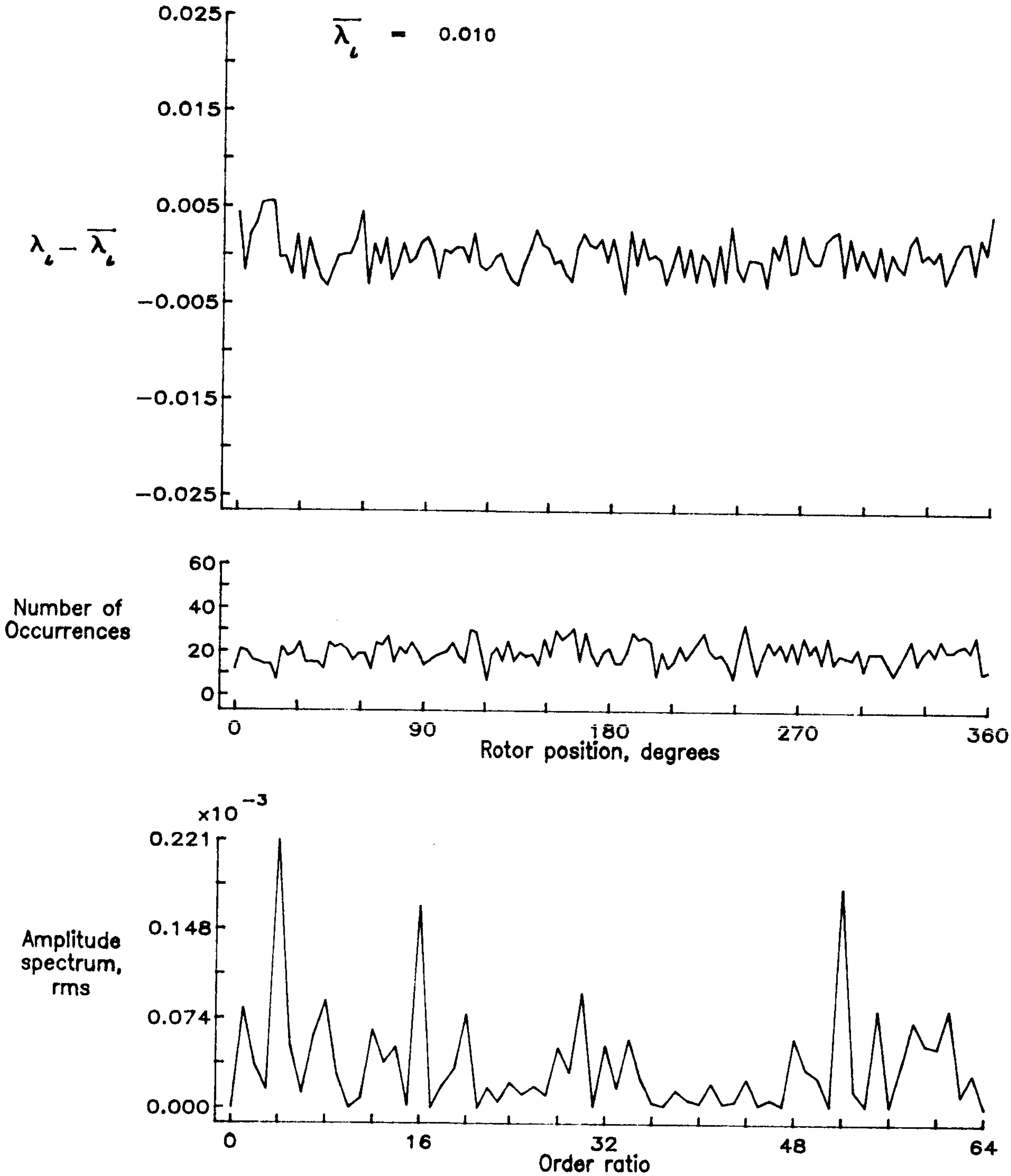


Figure 145.— Induced inflow velocity measured at 240 degrees and r/R of 1.02.



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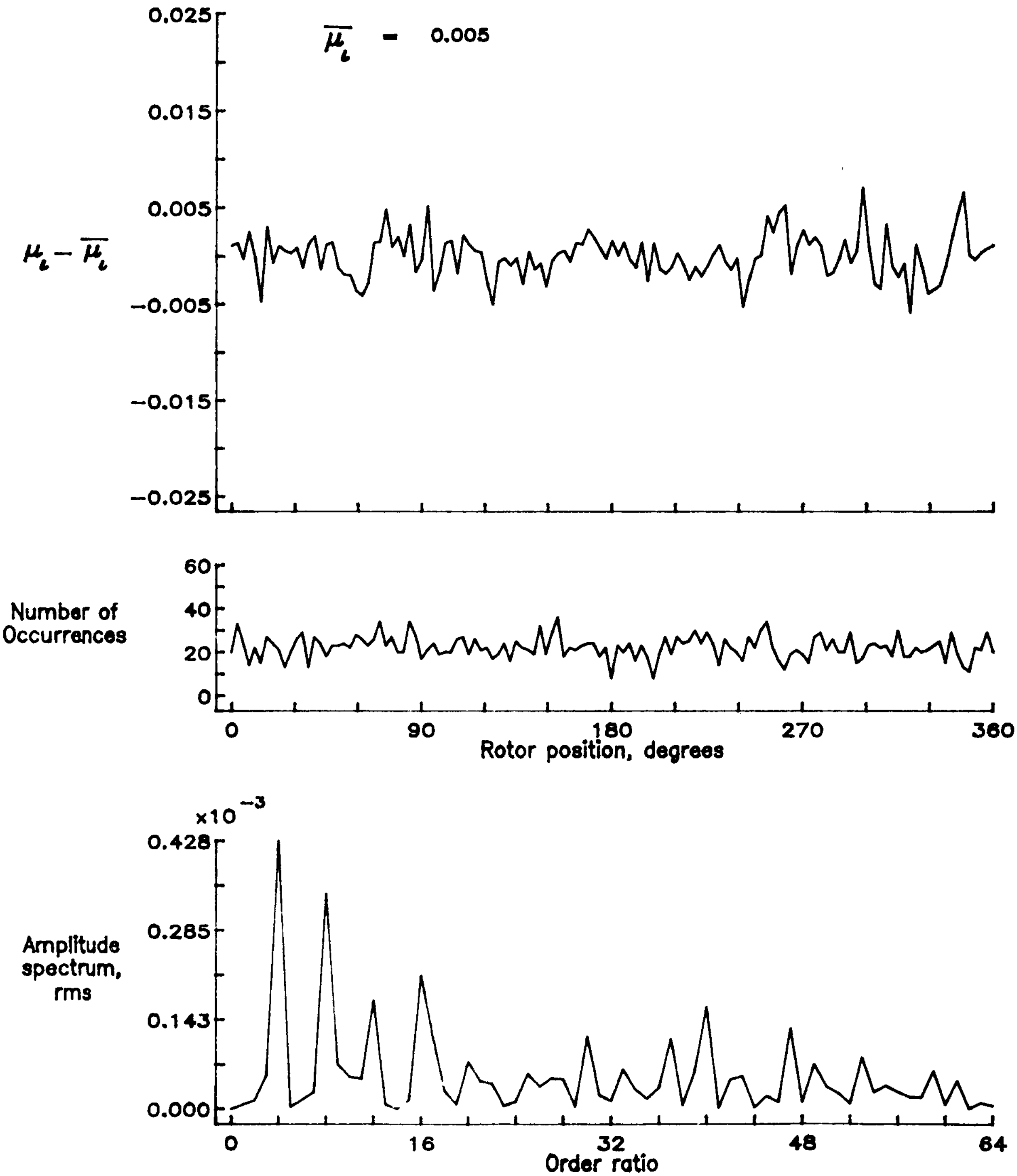
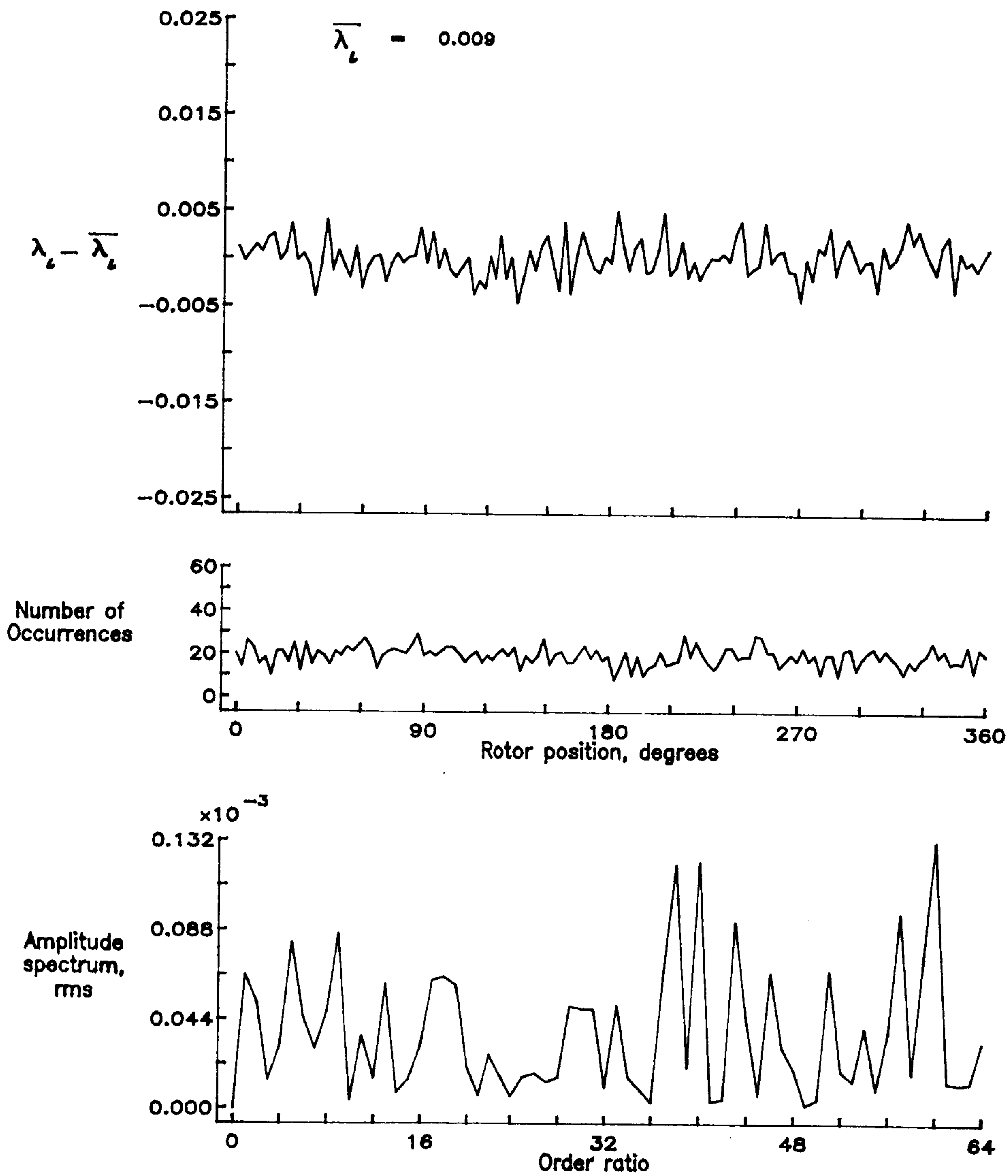


Figure 146.— Induced inflow velocity measured at 240 degrees and r/R of 1.04.



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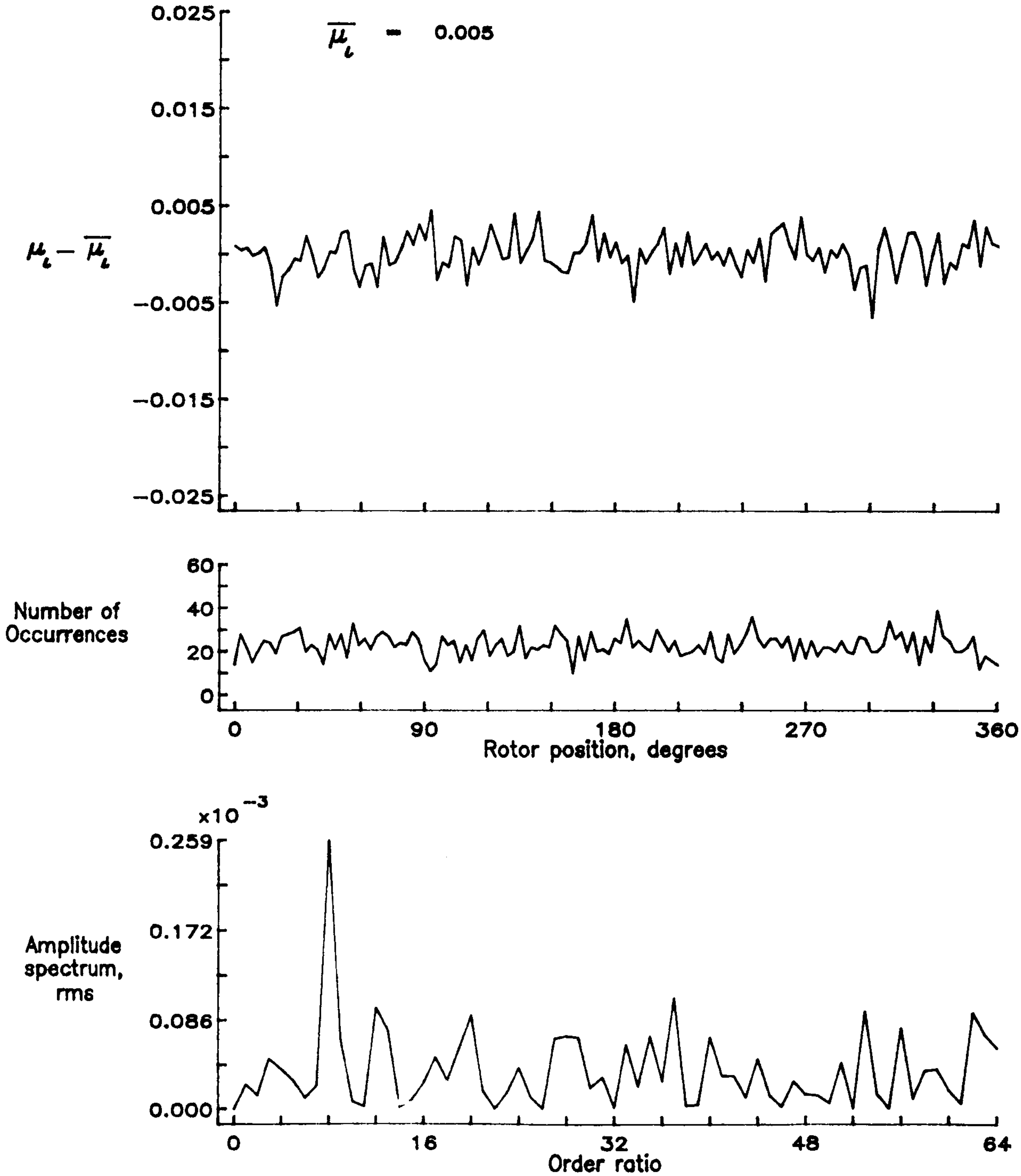
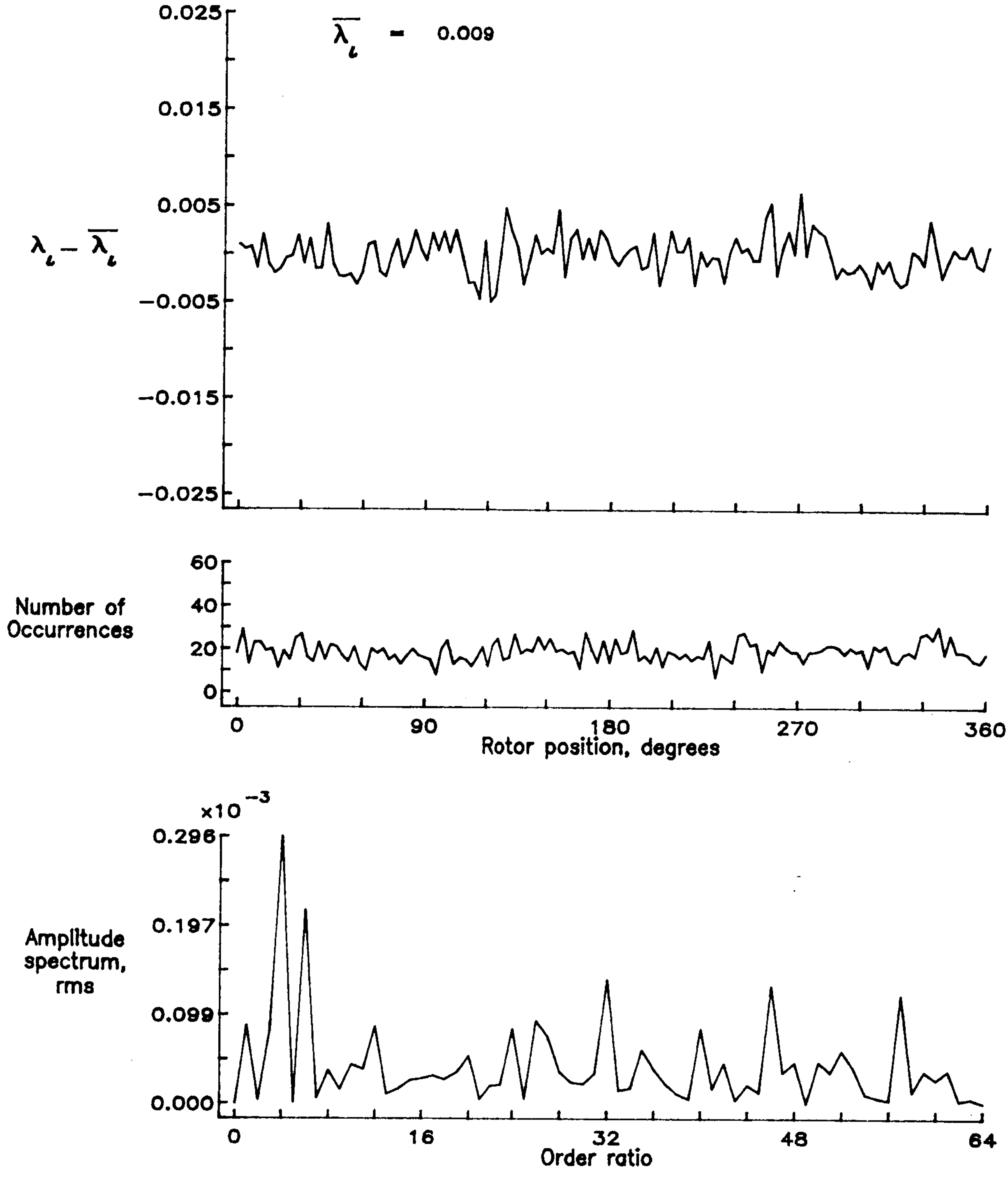


Figure 147.– Induced inflow velocity measured at 240 degrees and r/R of 1.10.



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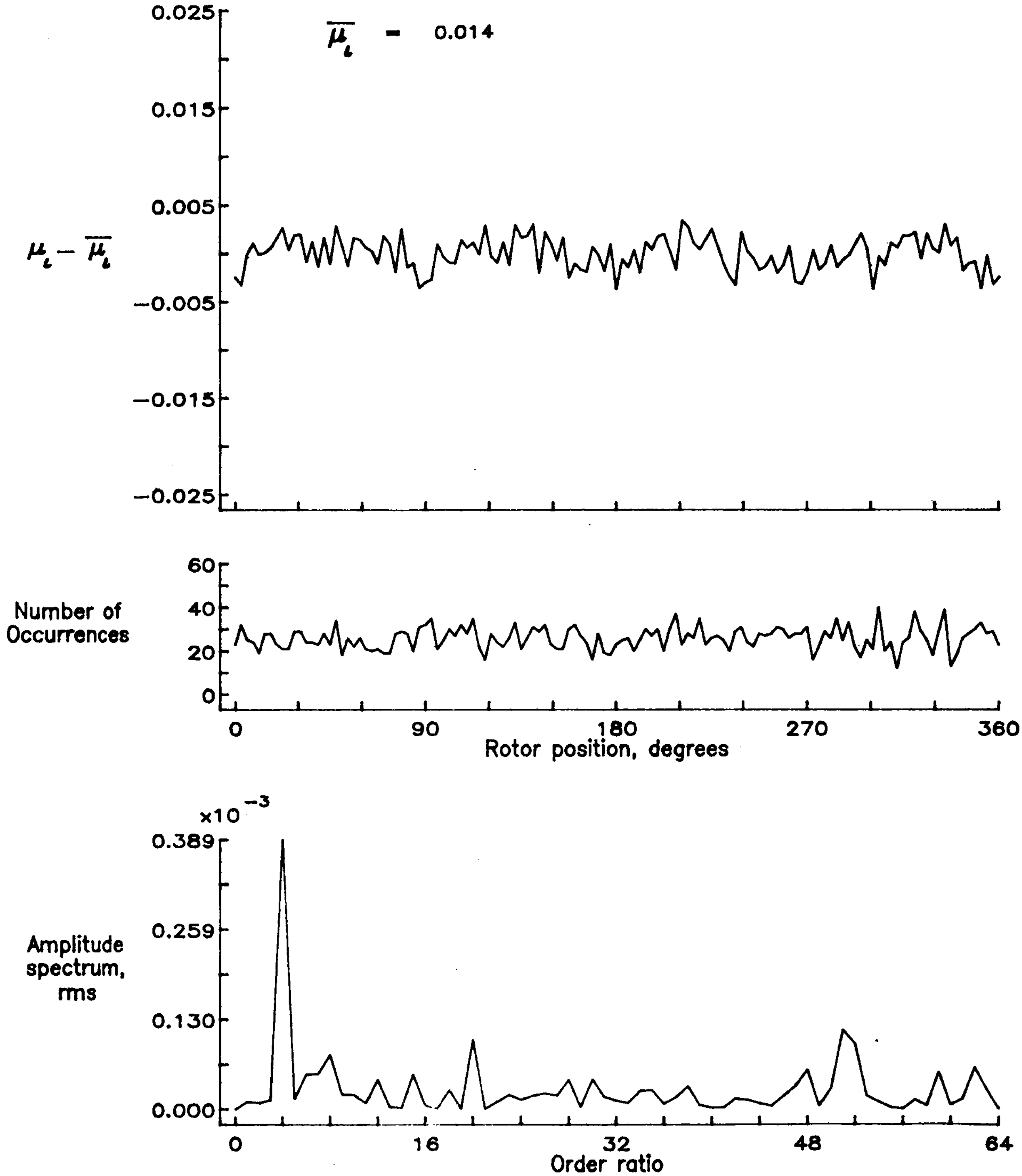
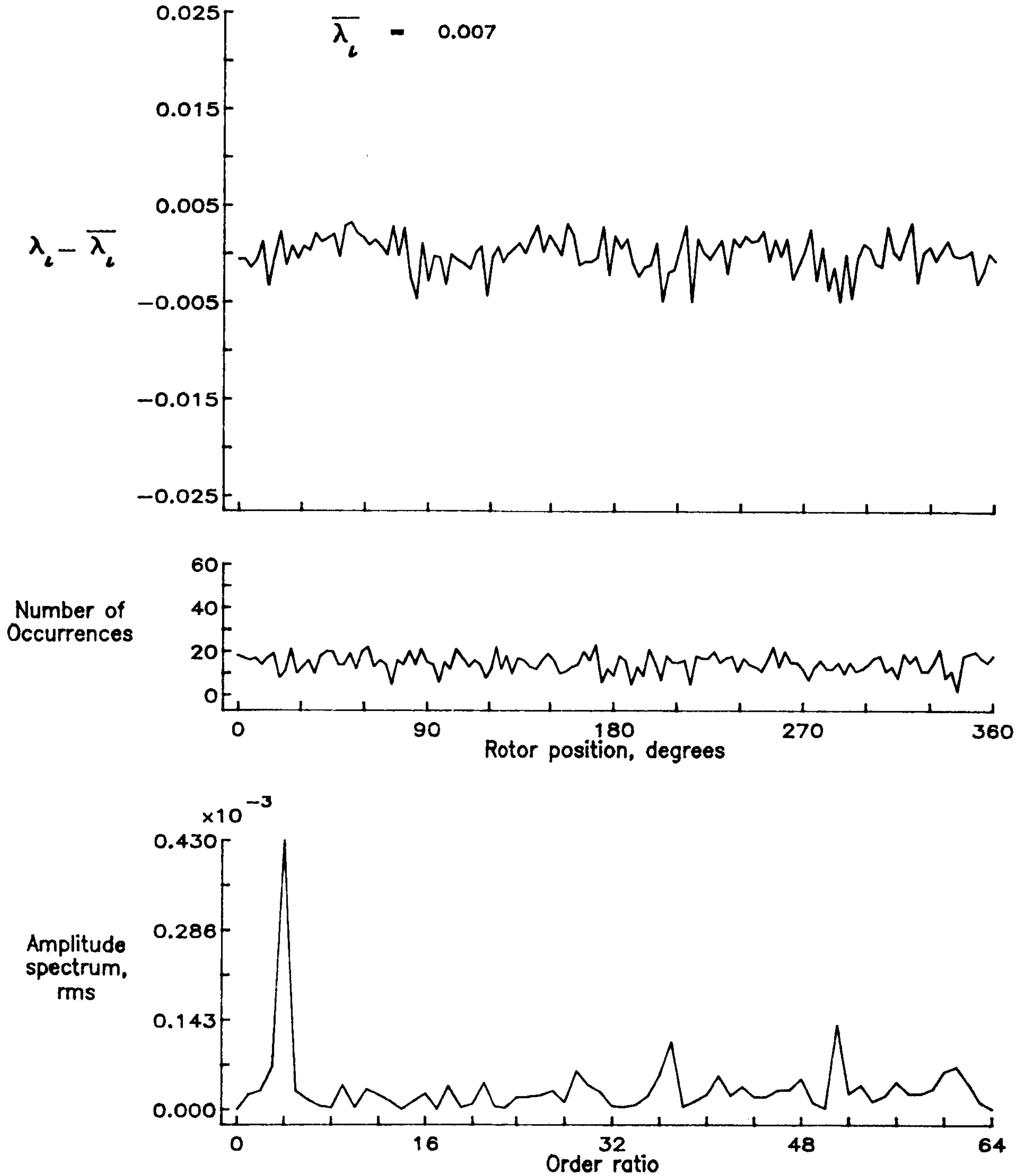


Figure 148.– Induced inflow velocity measured at 270 degrees and r/R of 0.20.



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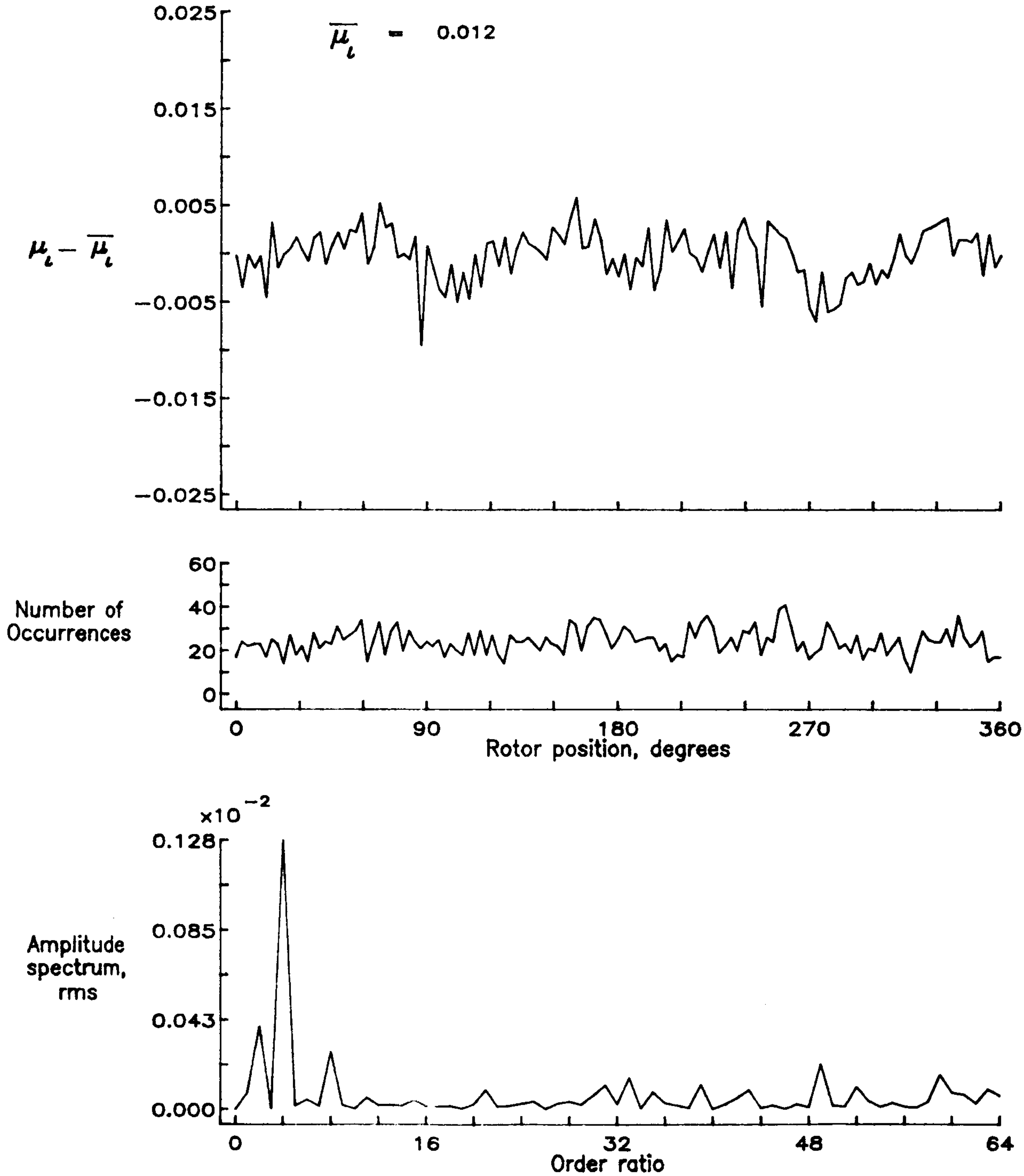
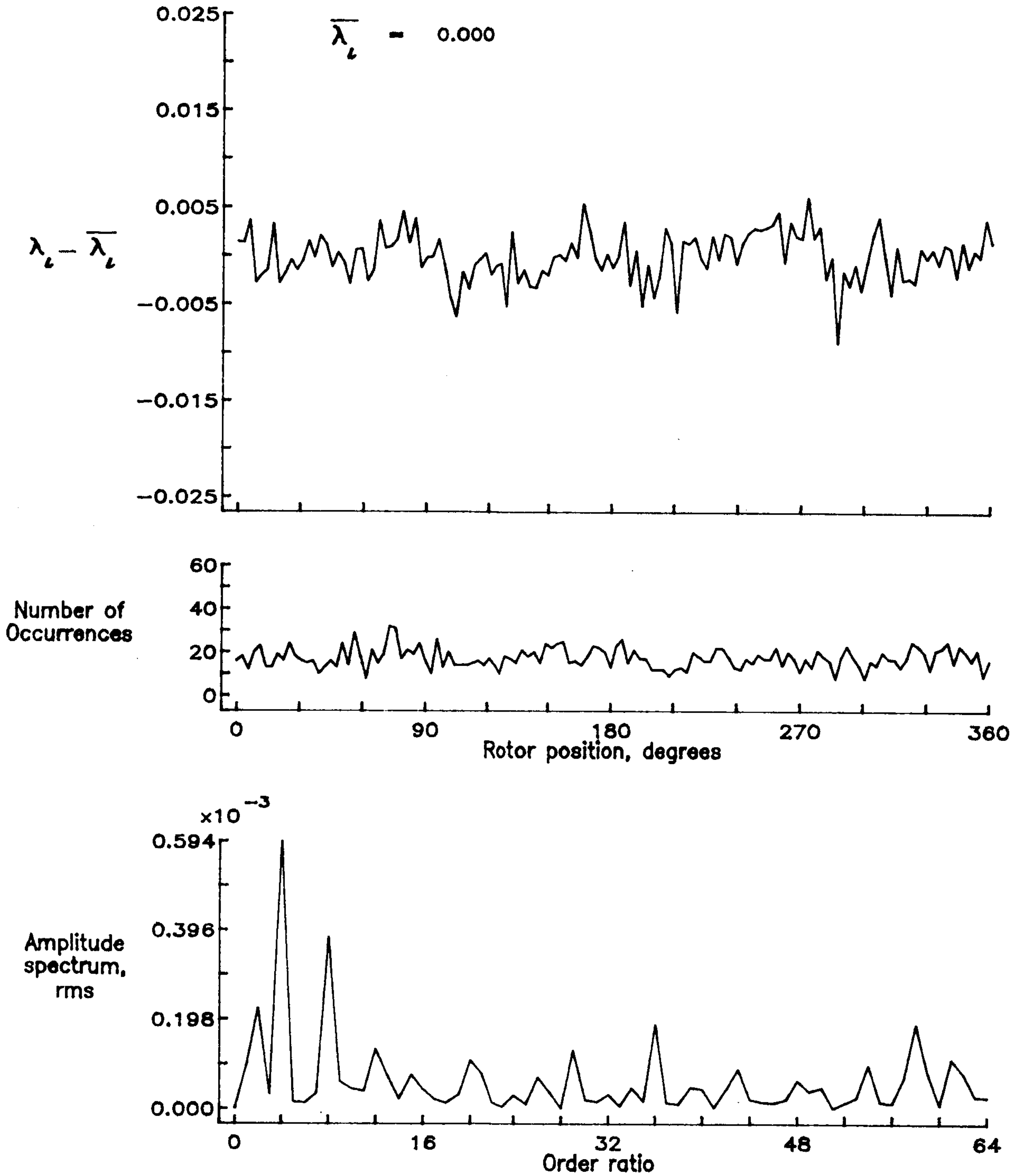


Figure 149.– Induced inflow velocity measured at 270 degrees and r/R of 0.40.



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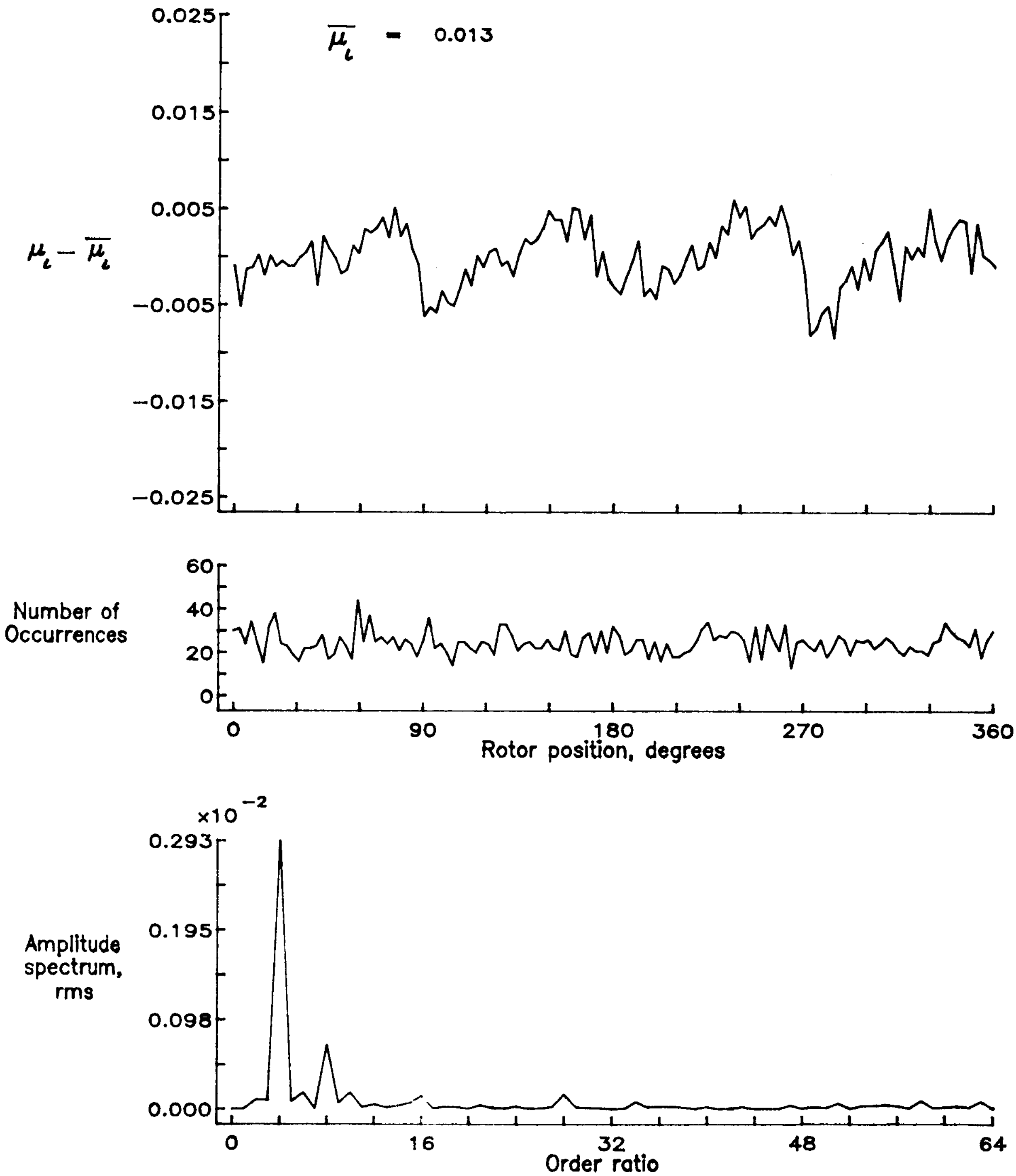
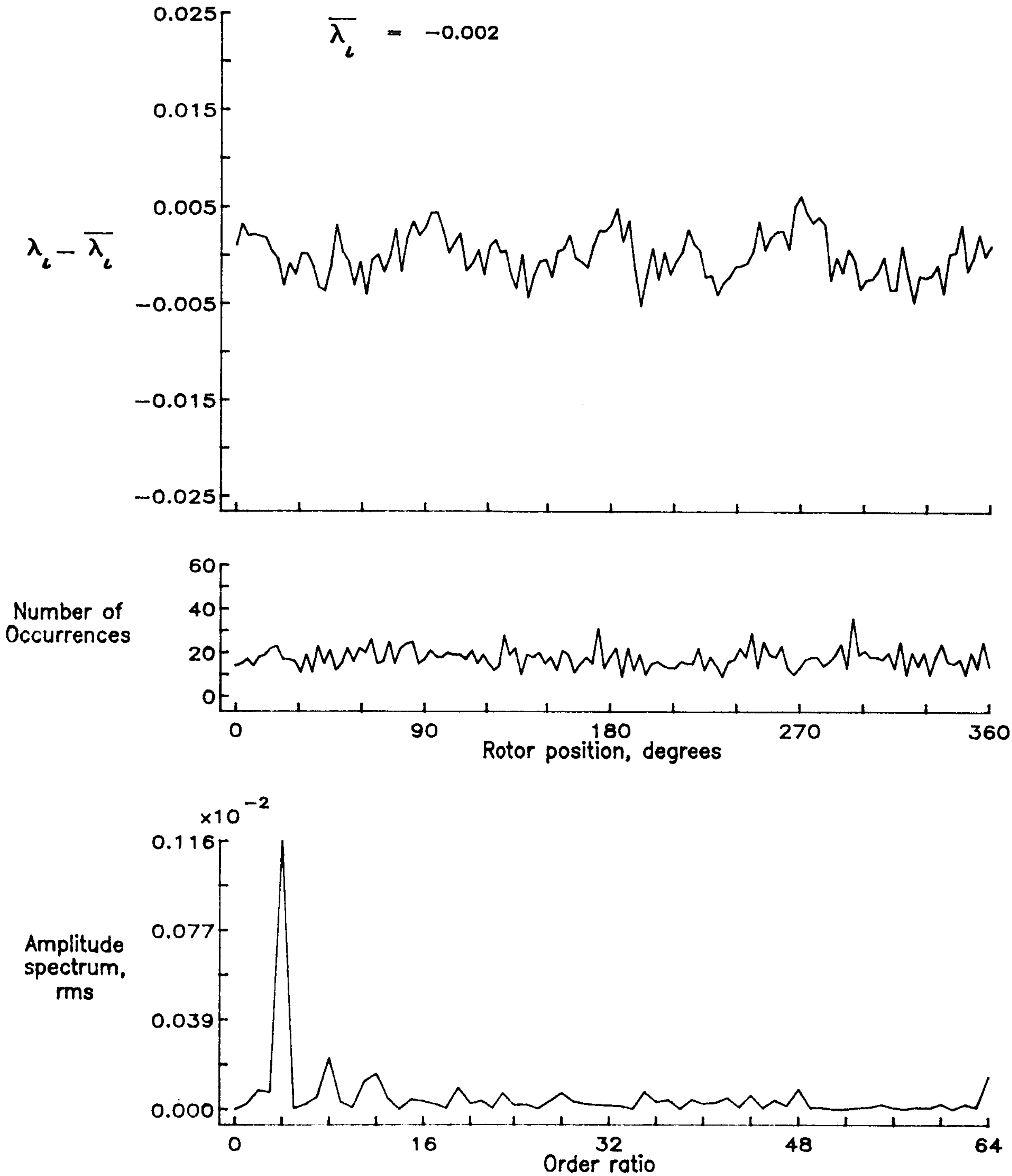


Figure 150.– Induced inflow velocity measured at 270 degrees and r/R of 0.50.



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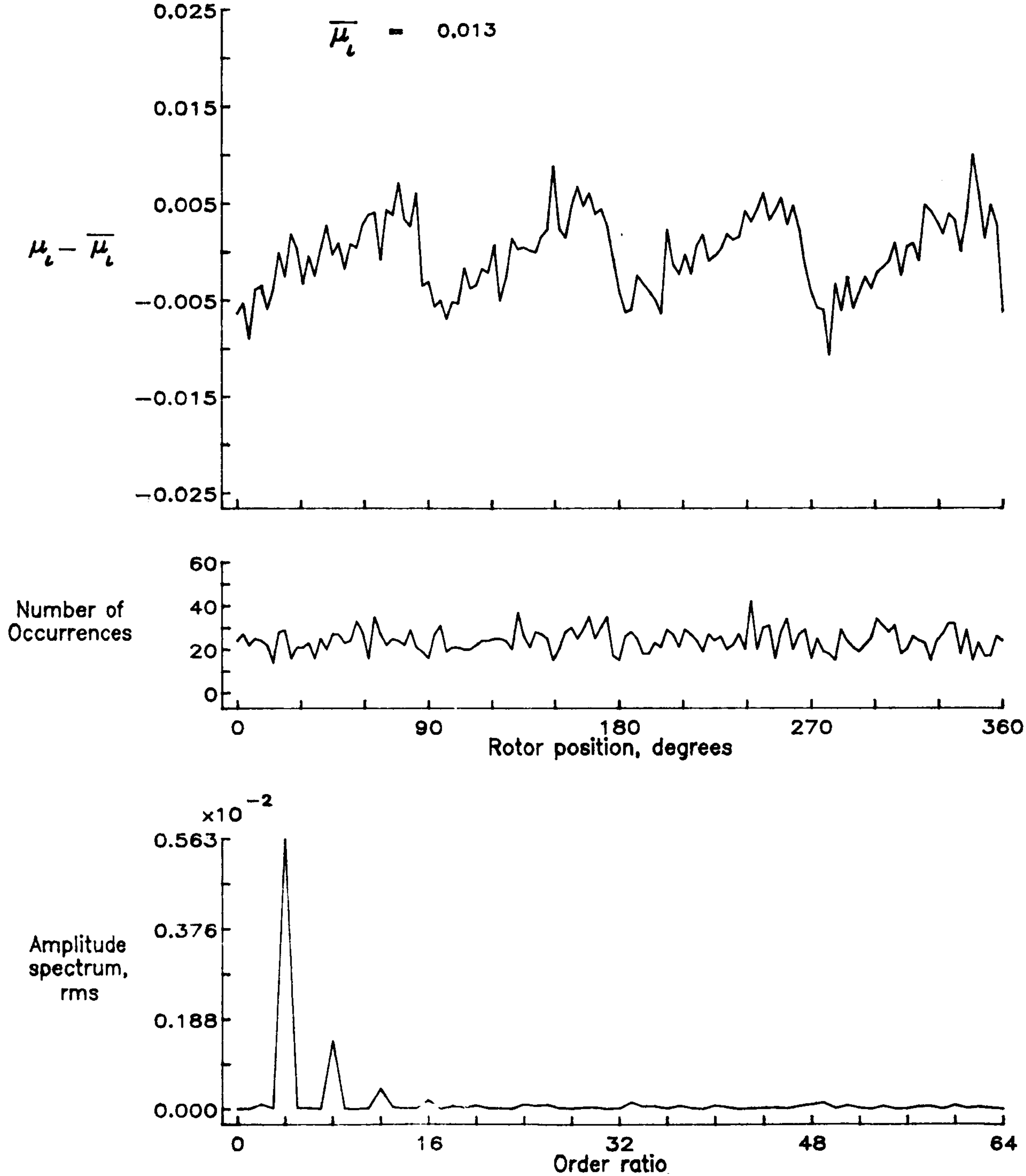
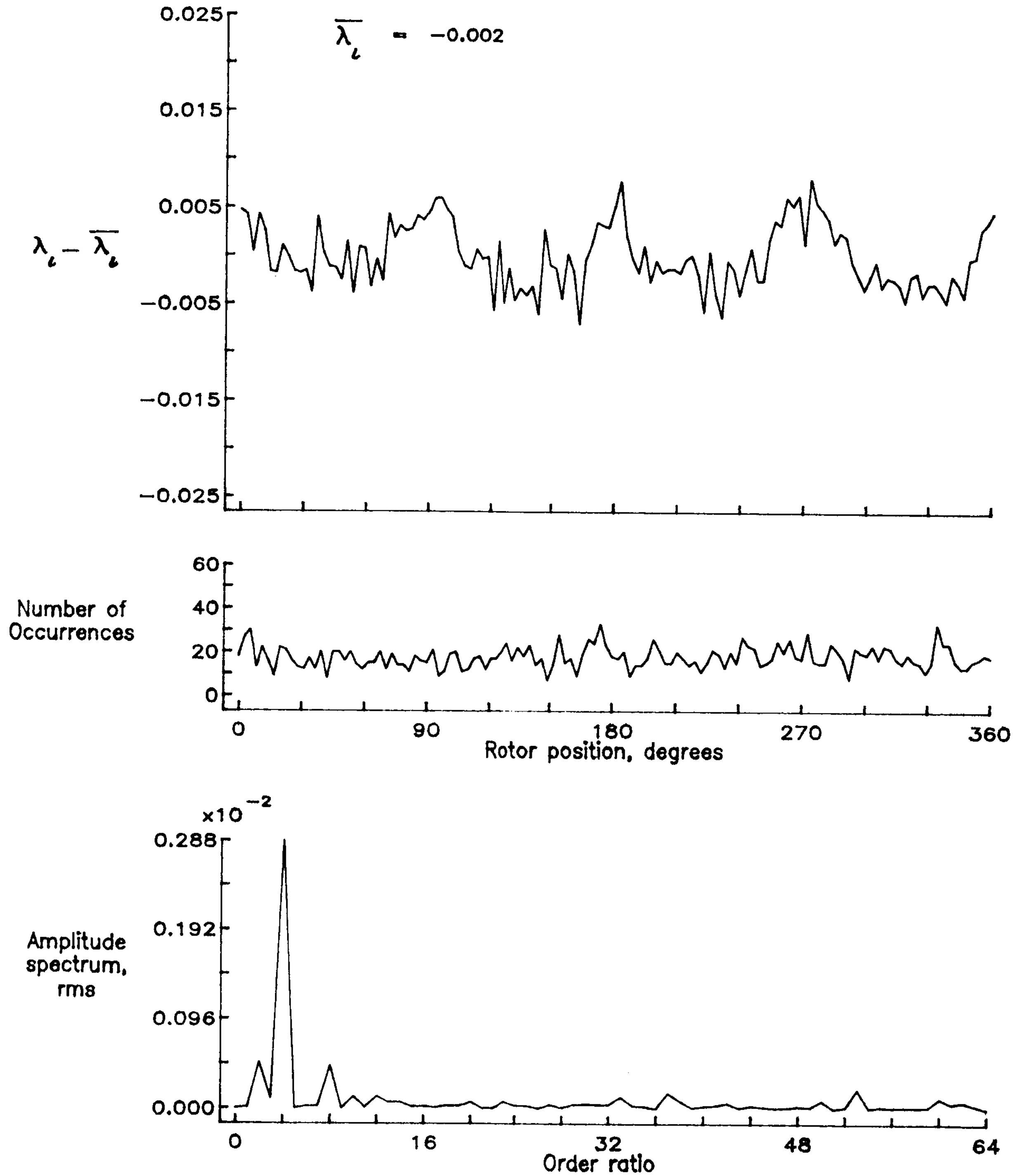


Figure 151.– Induced inflow velocity measured at 270 degrees and r/R of 0.60.



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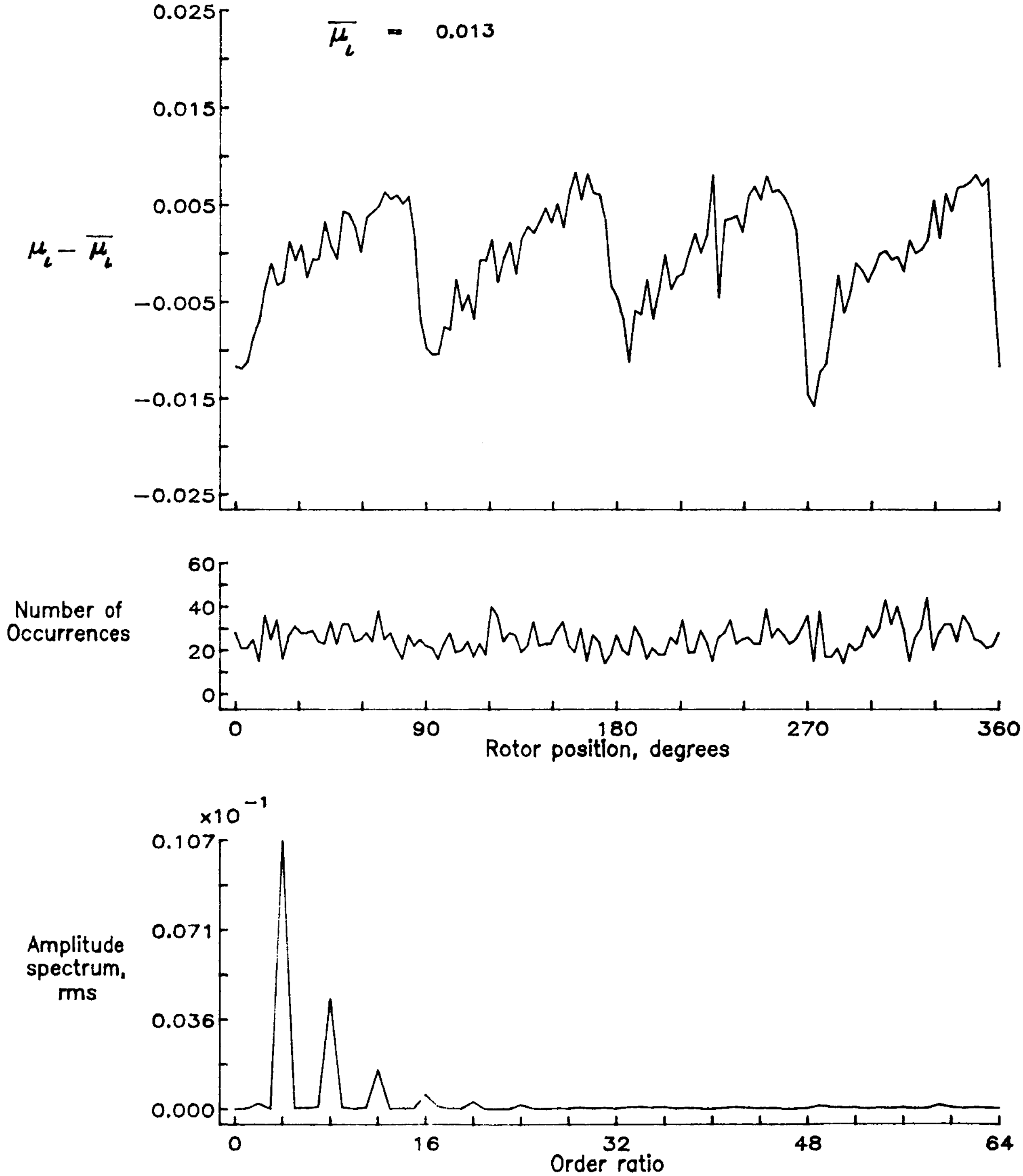
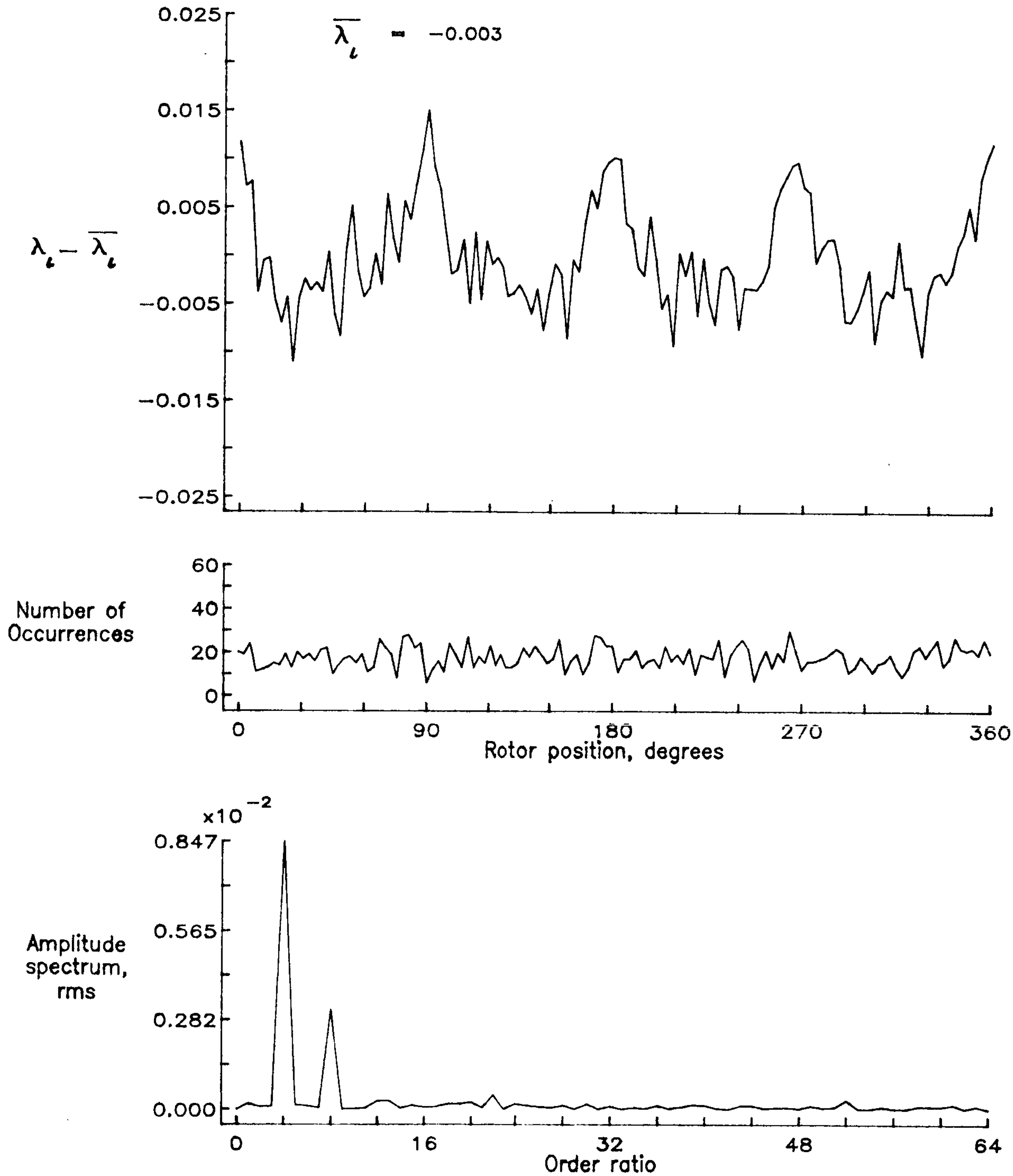


Figure 152.– Induced inflow velocity measured at 270 degrees and r/R of 0.70.



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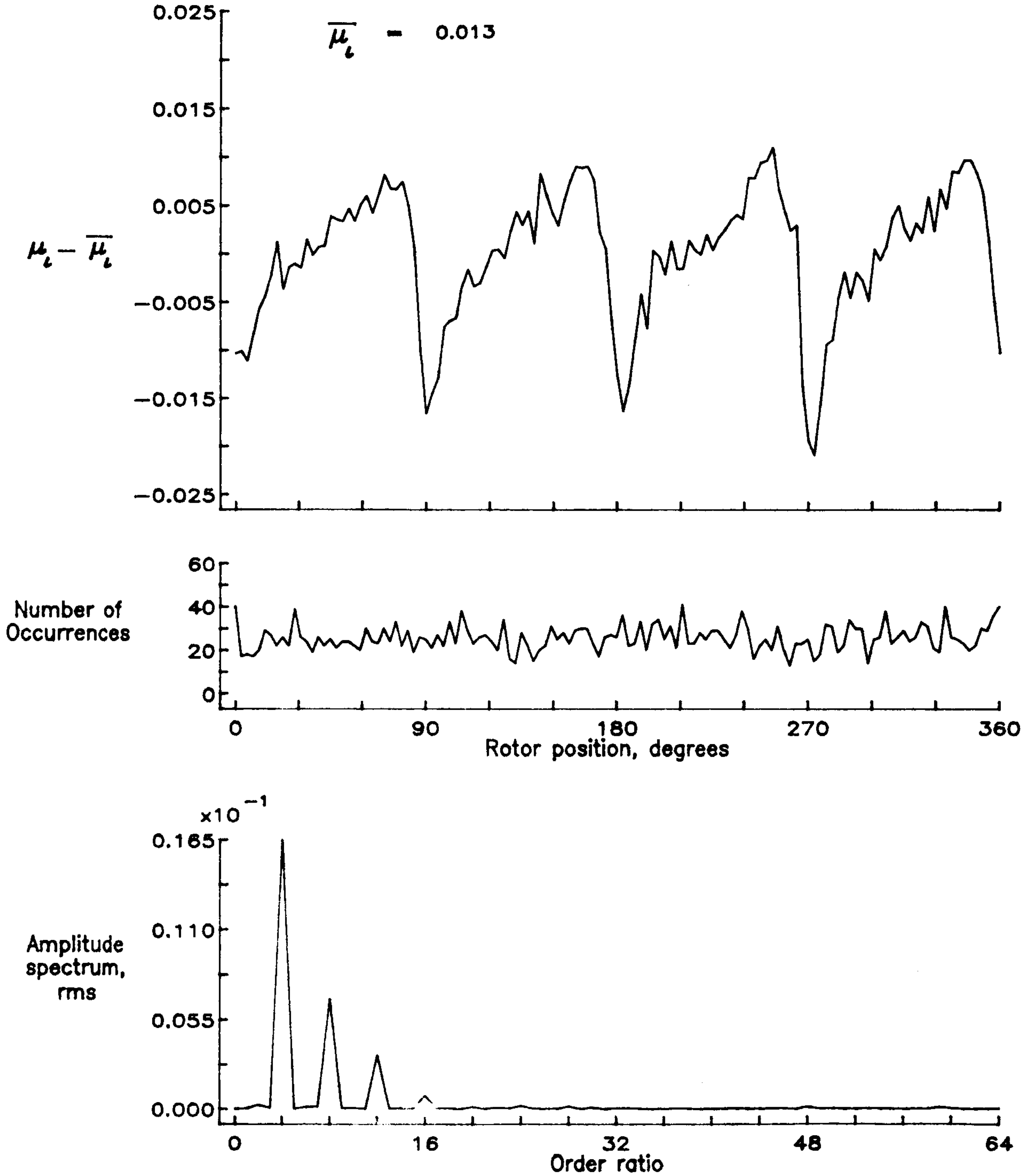
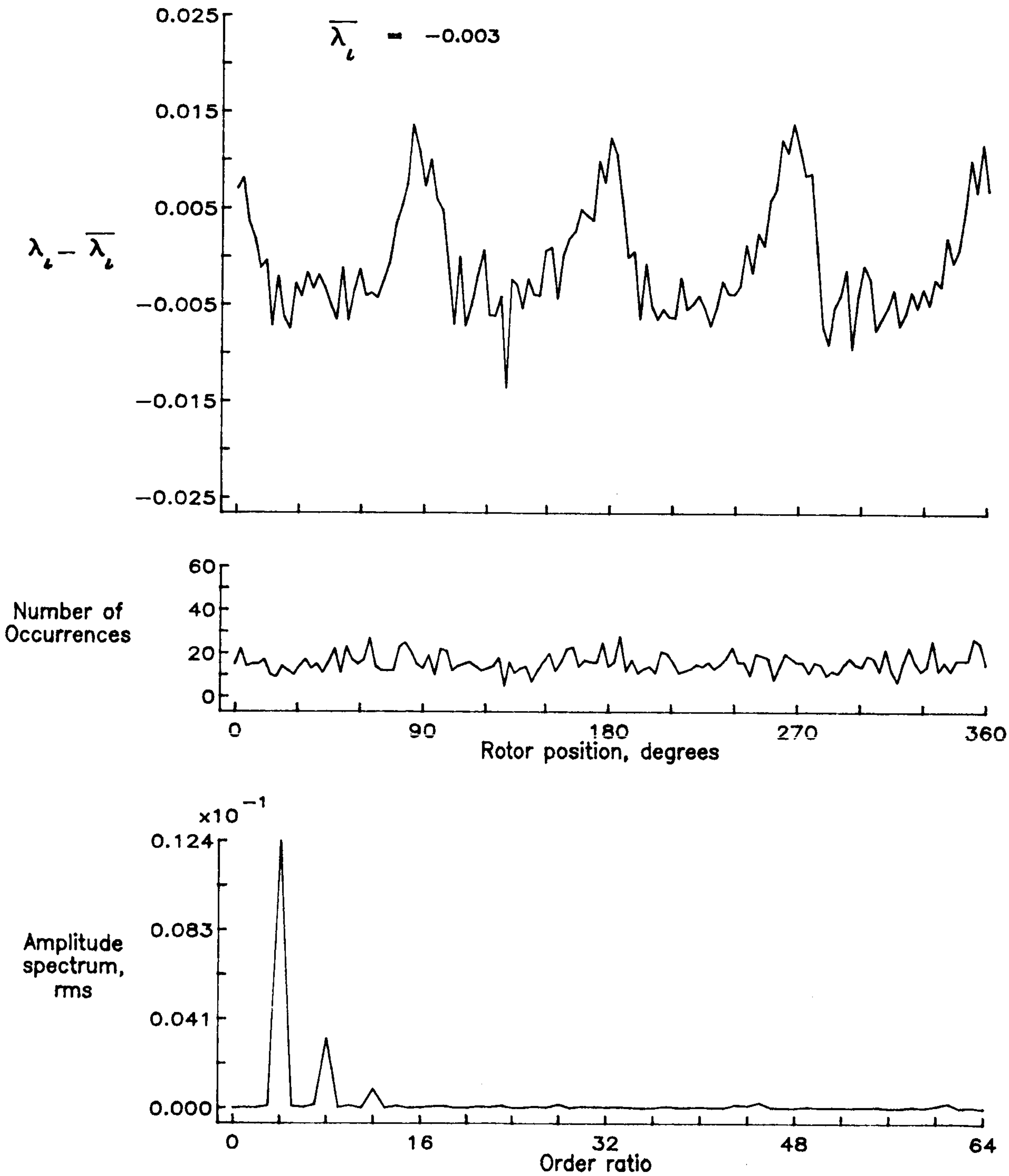


Figure 153.– Induced inflow velocity measured at 270 degrees and r/R of 0.74.



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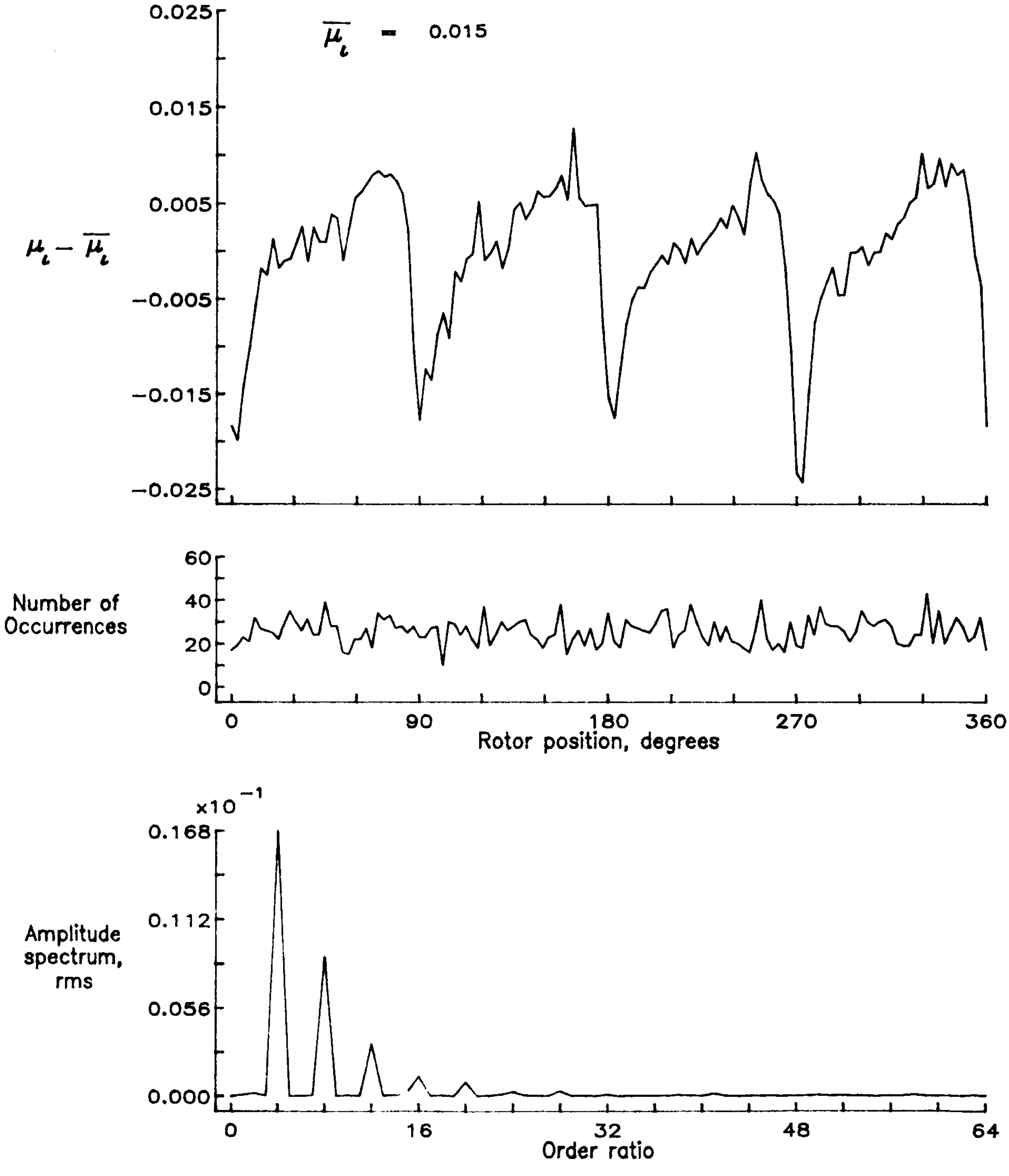
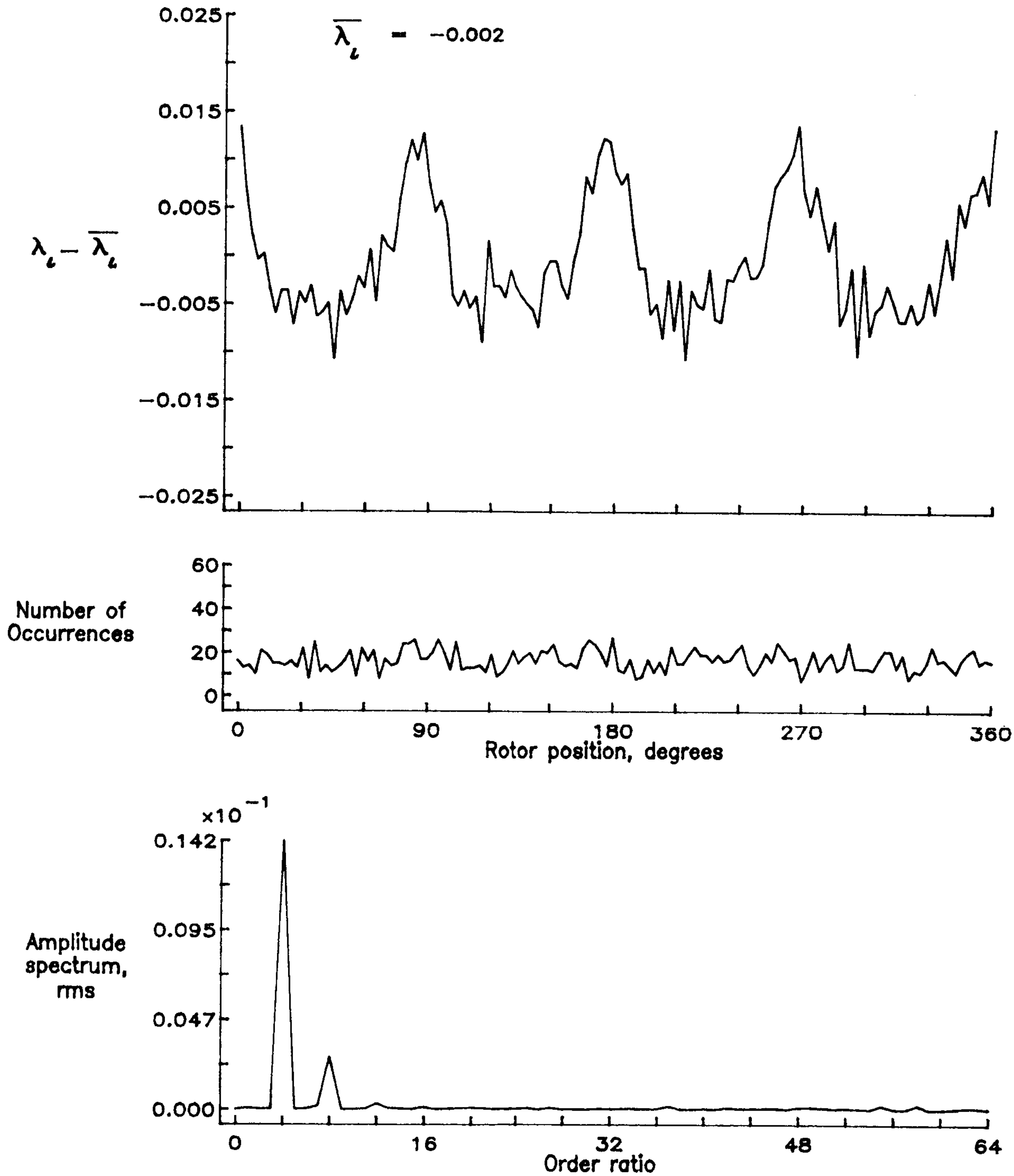


Figure 154.– Induced inflow velocity measured at 270 degrees and r/R of 0.78.



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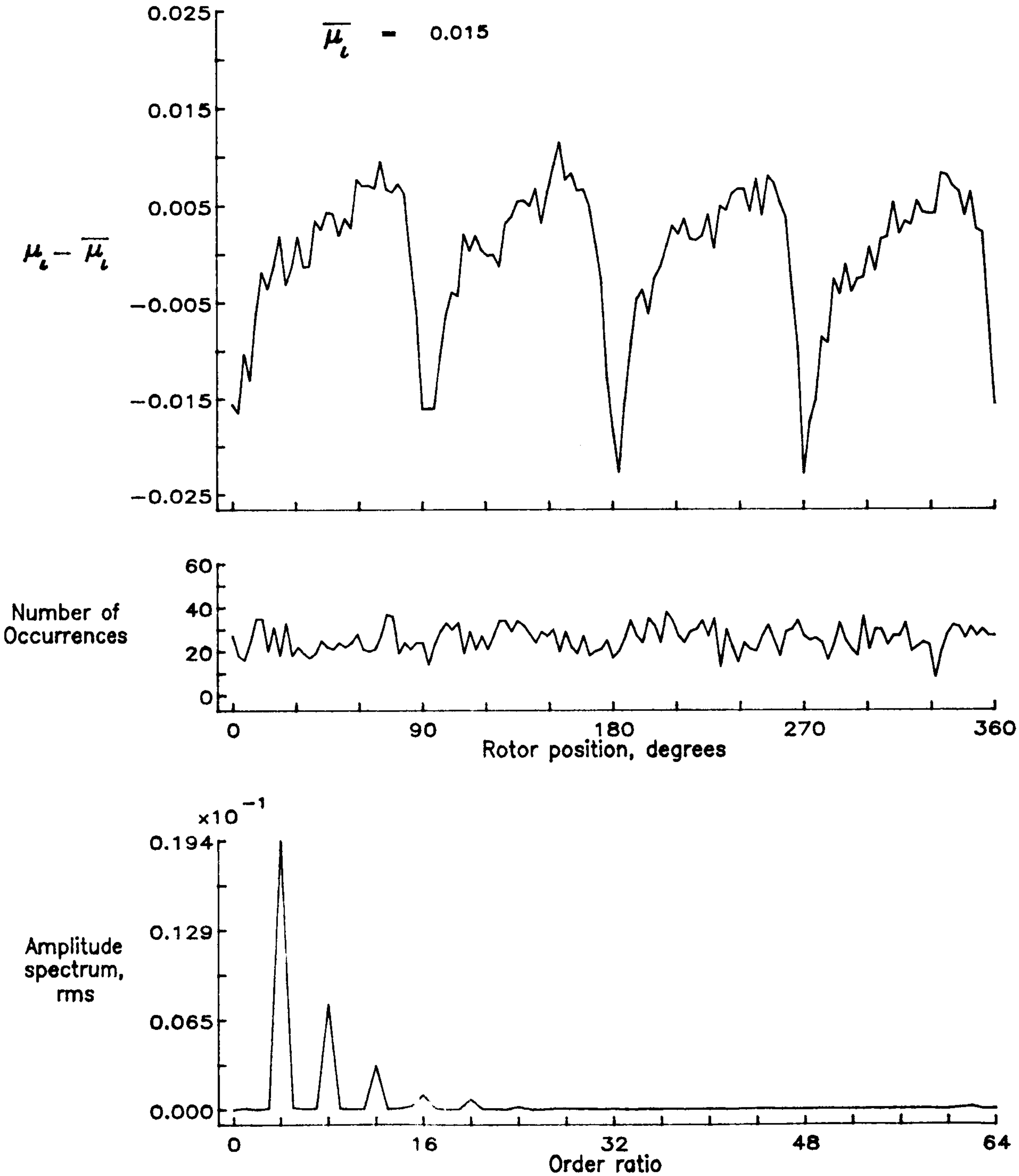
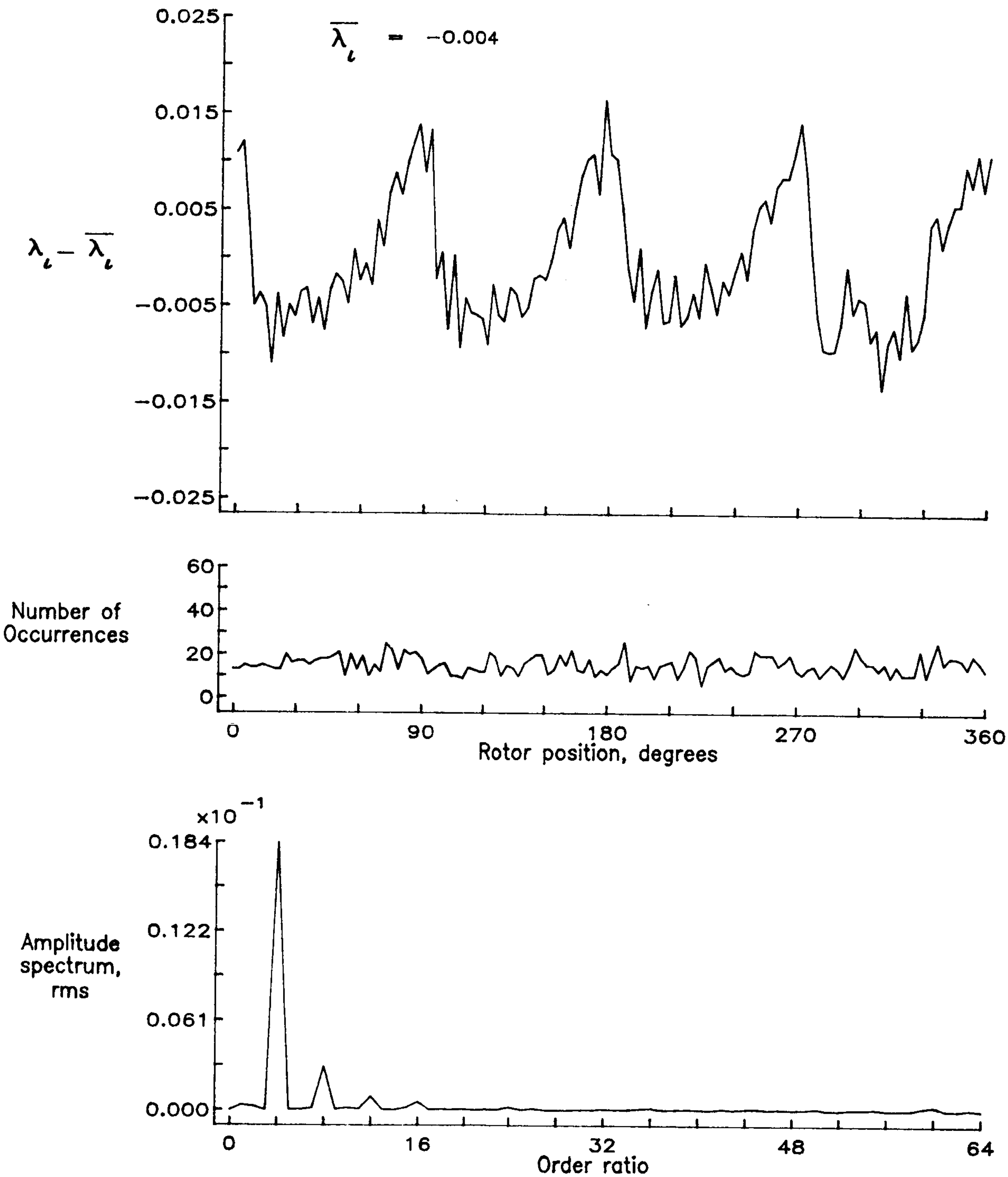


Figure 155.— Induced inflow velocity measured at 270 degrees and r/R of 0.82.



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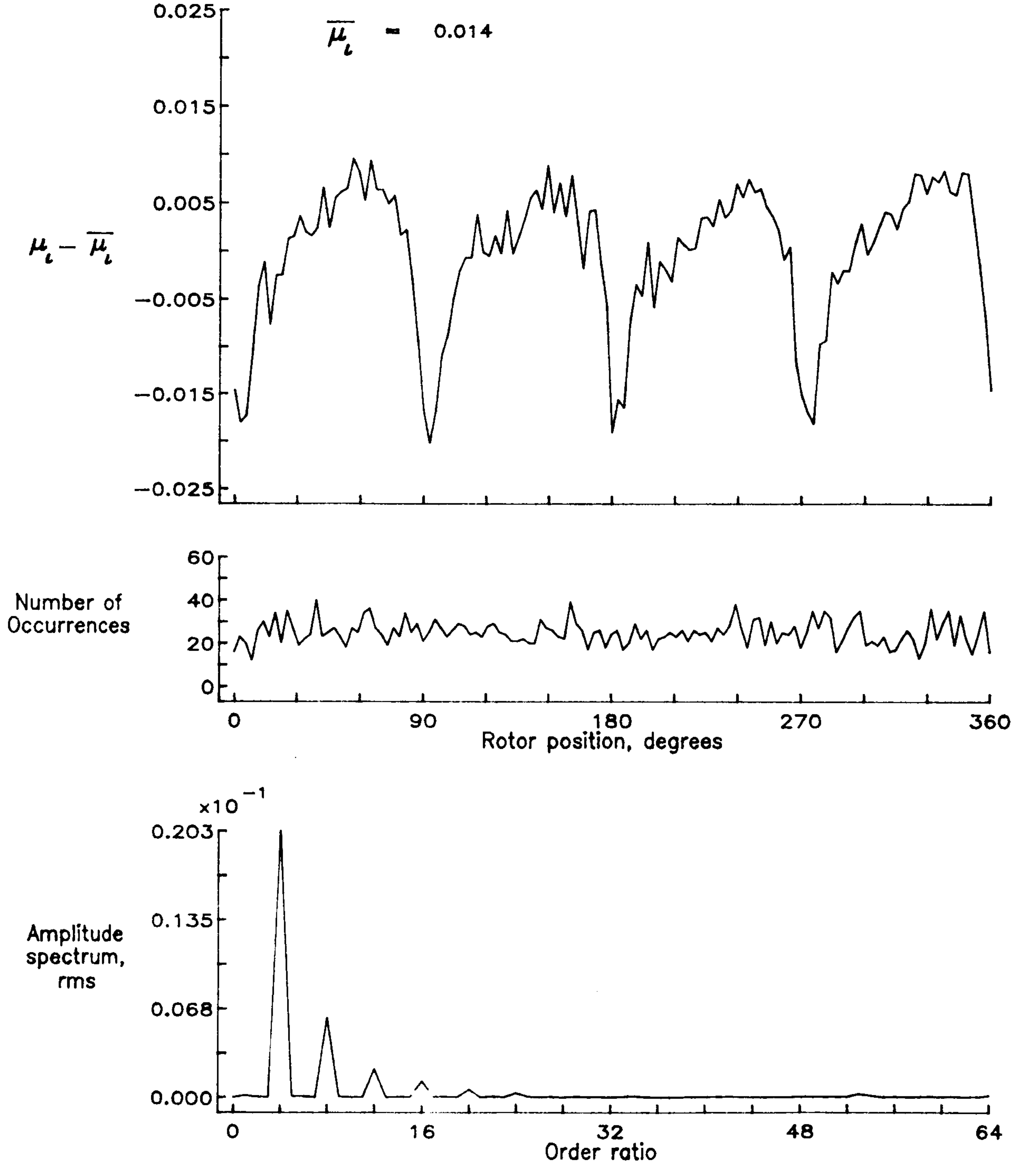
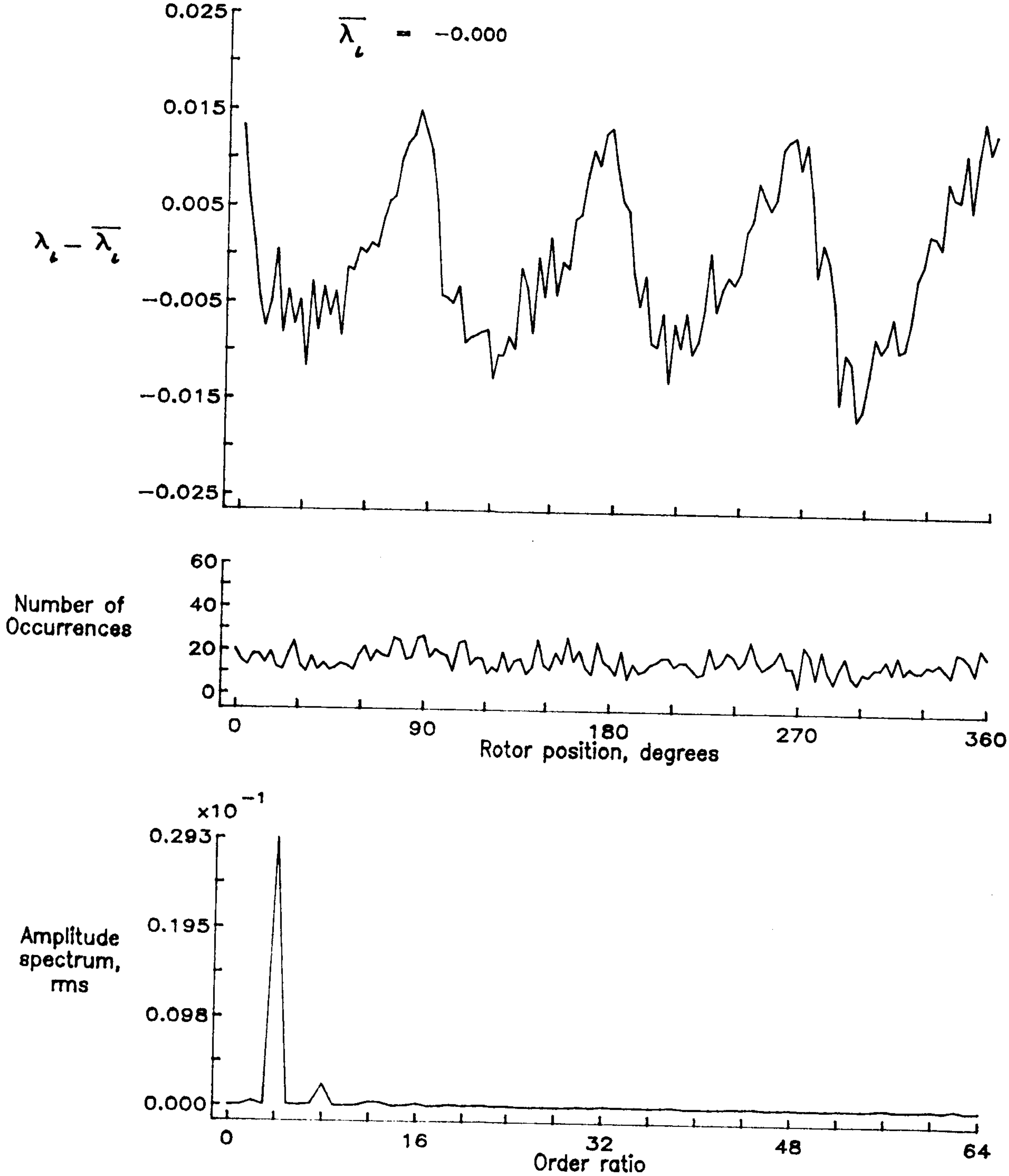


Figure 156.— Induced inflow velocity measured at 270 degrees and r/R of 0.86.



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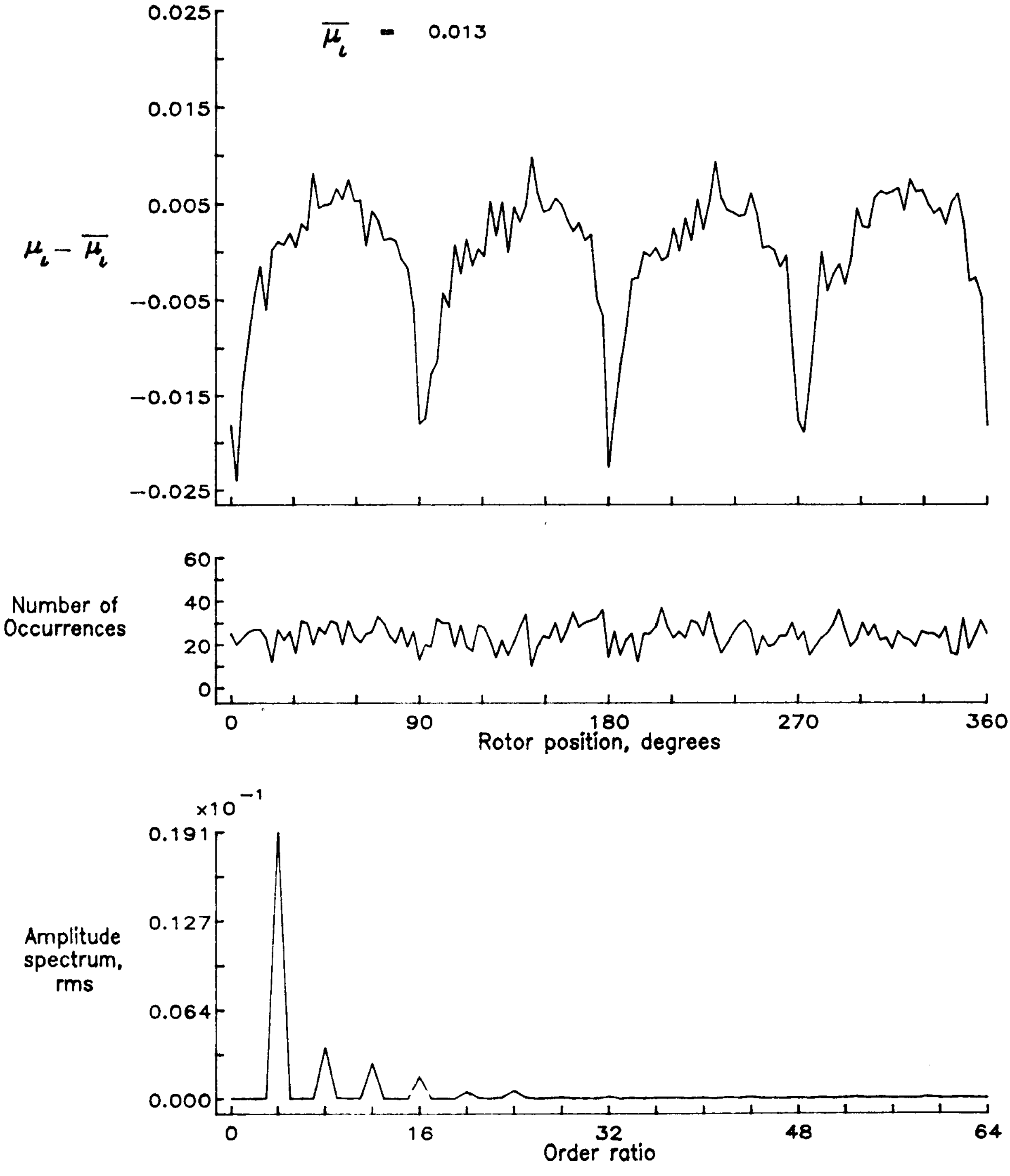
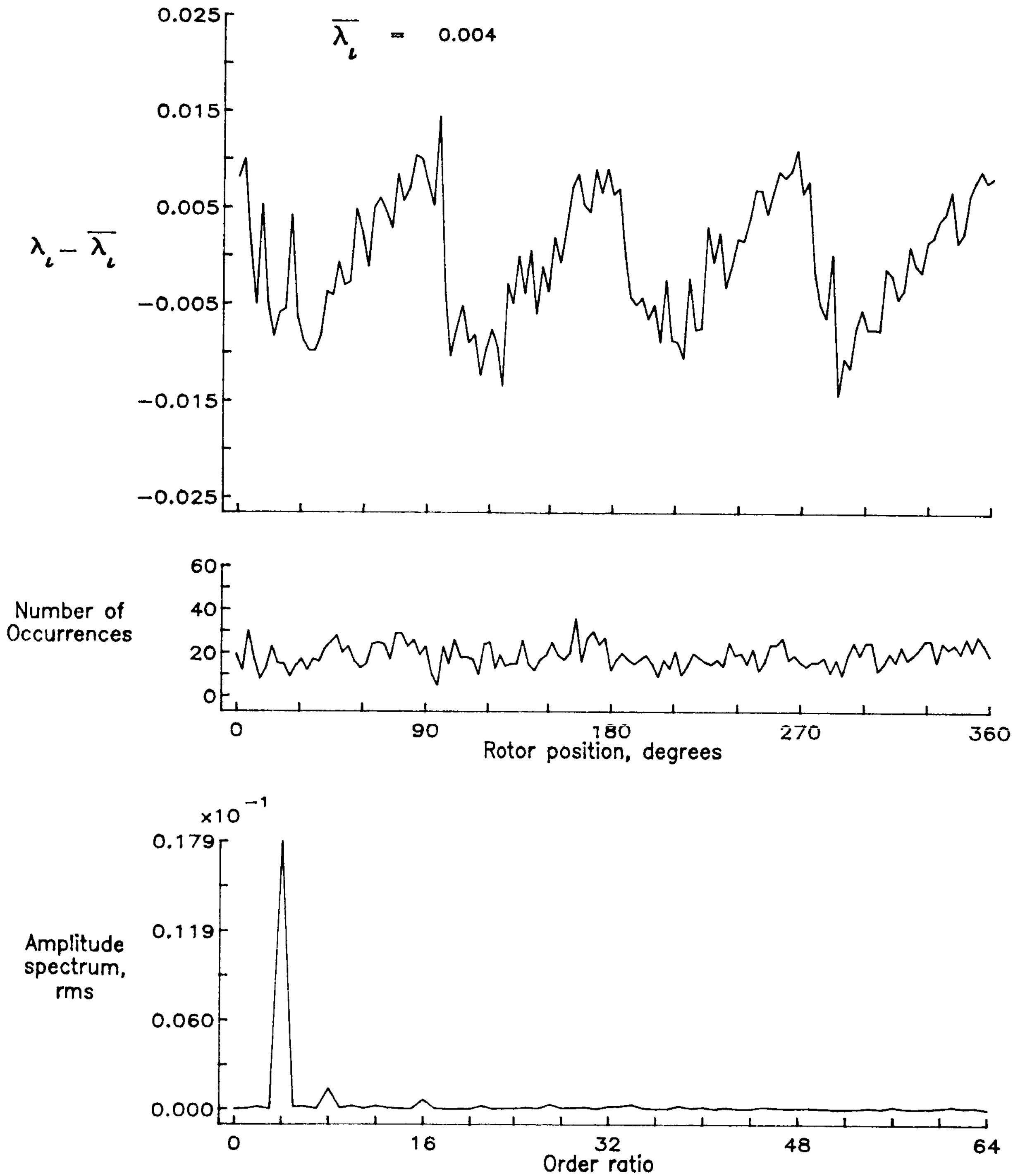


Figure 157.– Induced inflow velocity measured at 270 degrees and r/R of 0.90.



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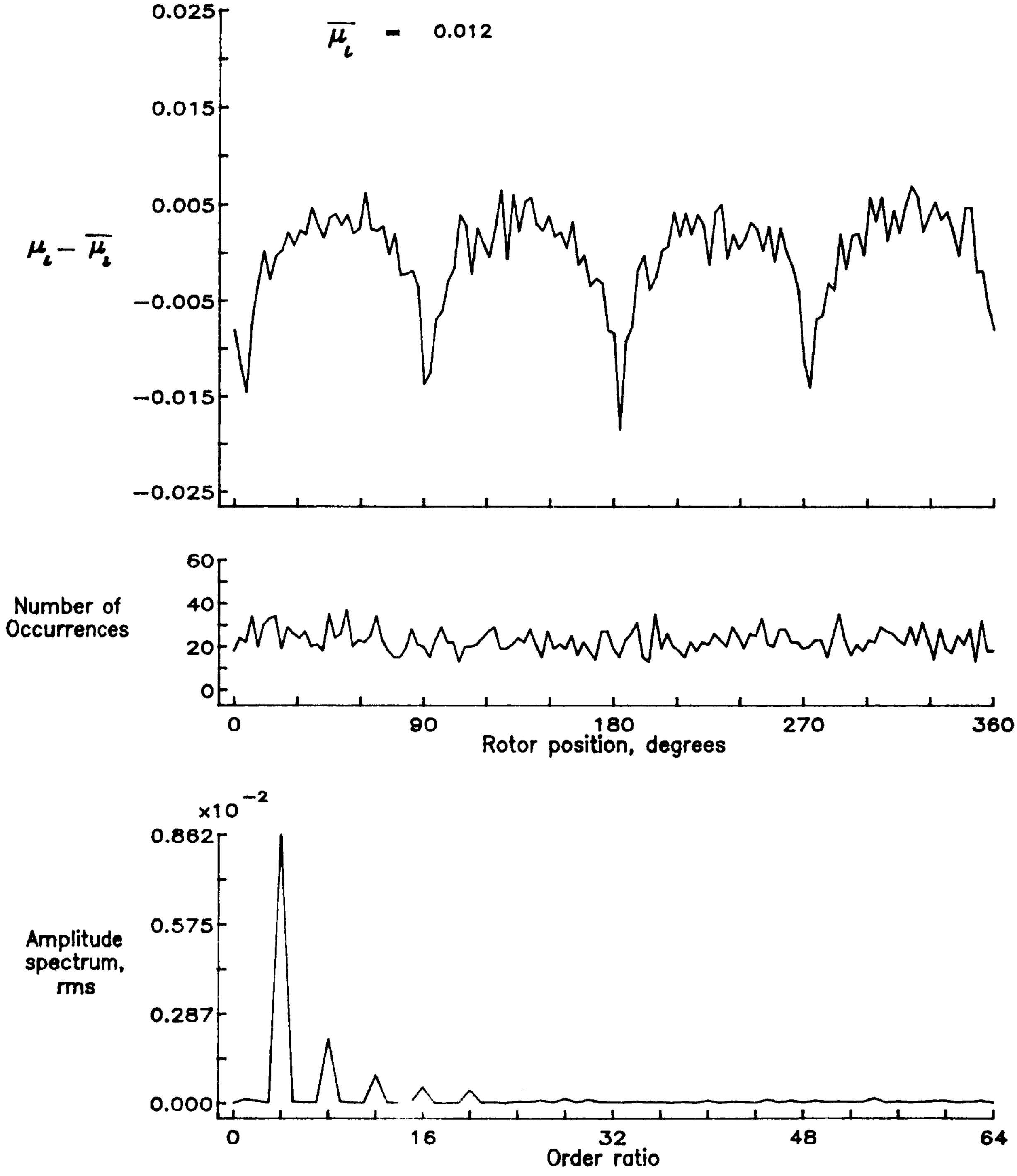
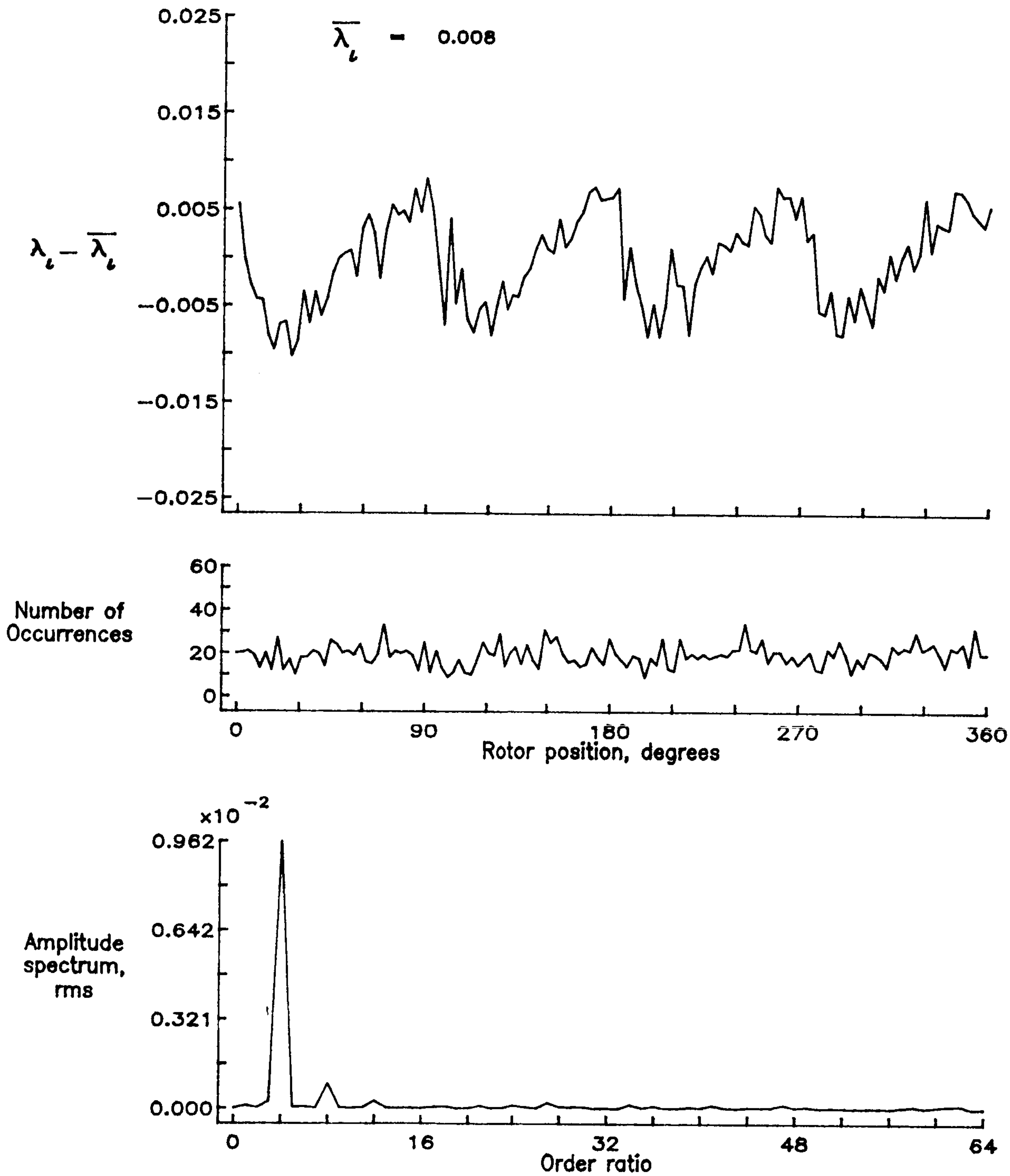


Figure 158.— Induced inflow velocity measured at 270 degrees and r/R of 0.94.



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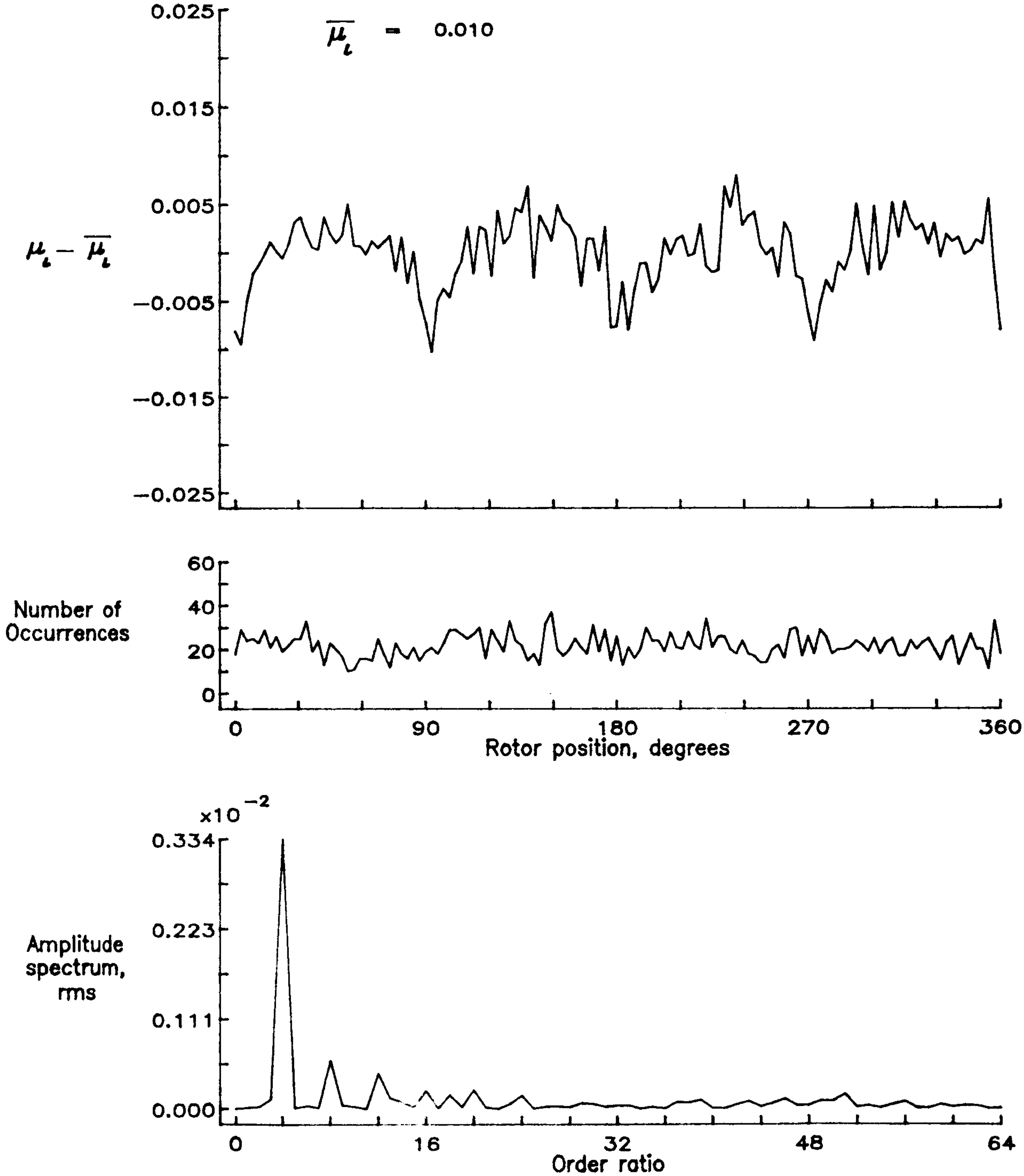


Figure 159.– Induced inflow velocity measured at 270 degrees and r/R of 0.98.

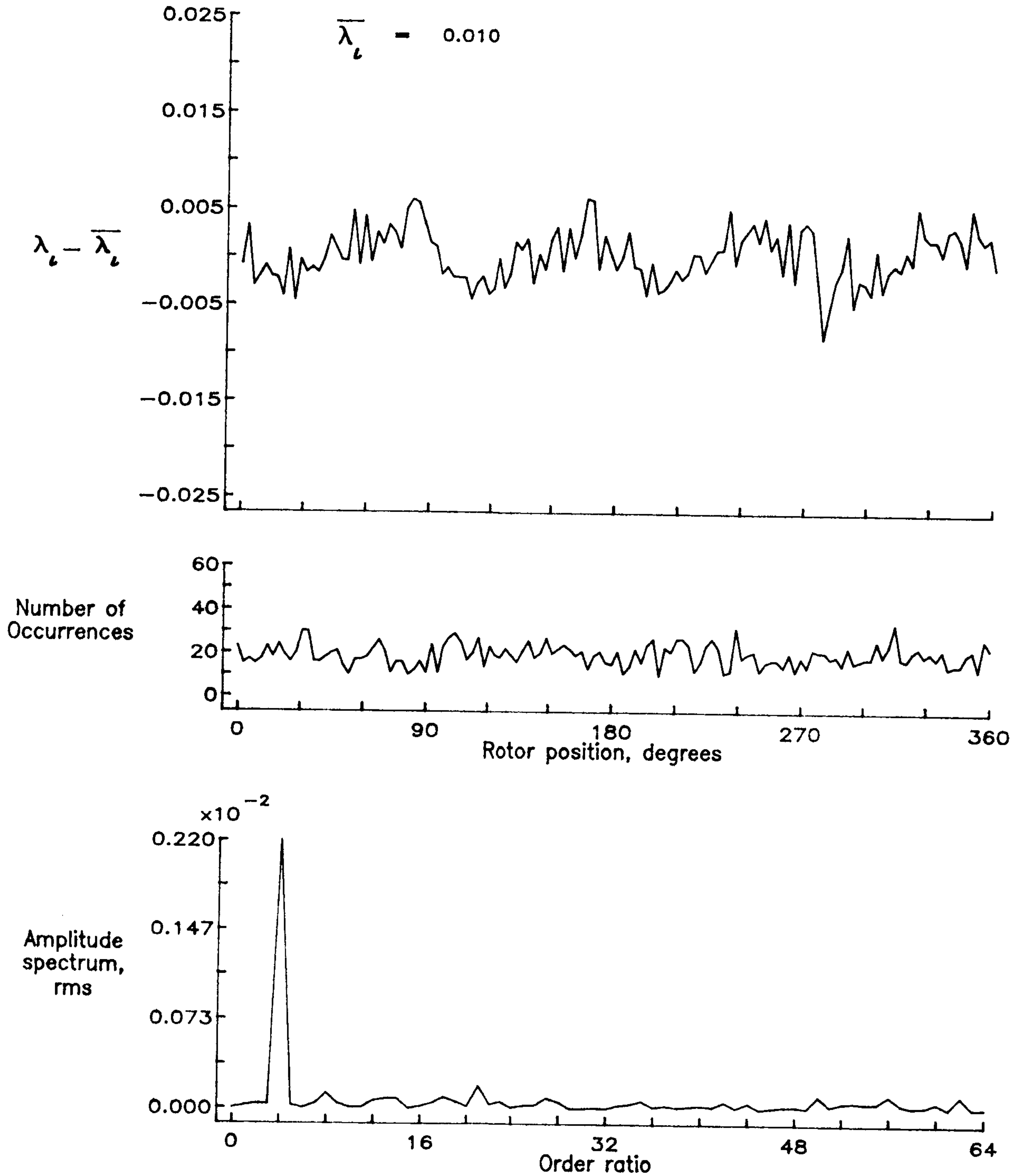


Figure 159.– Concluded.

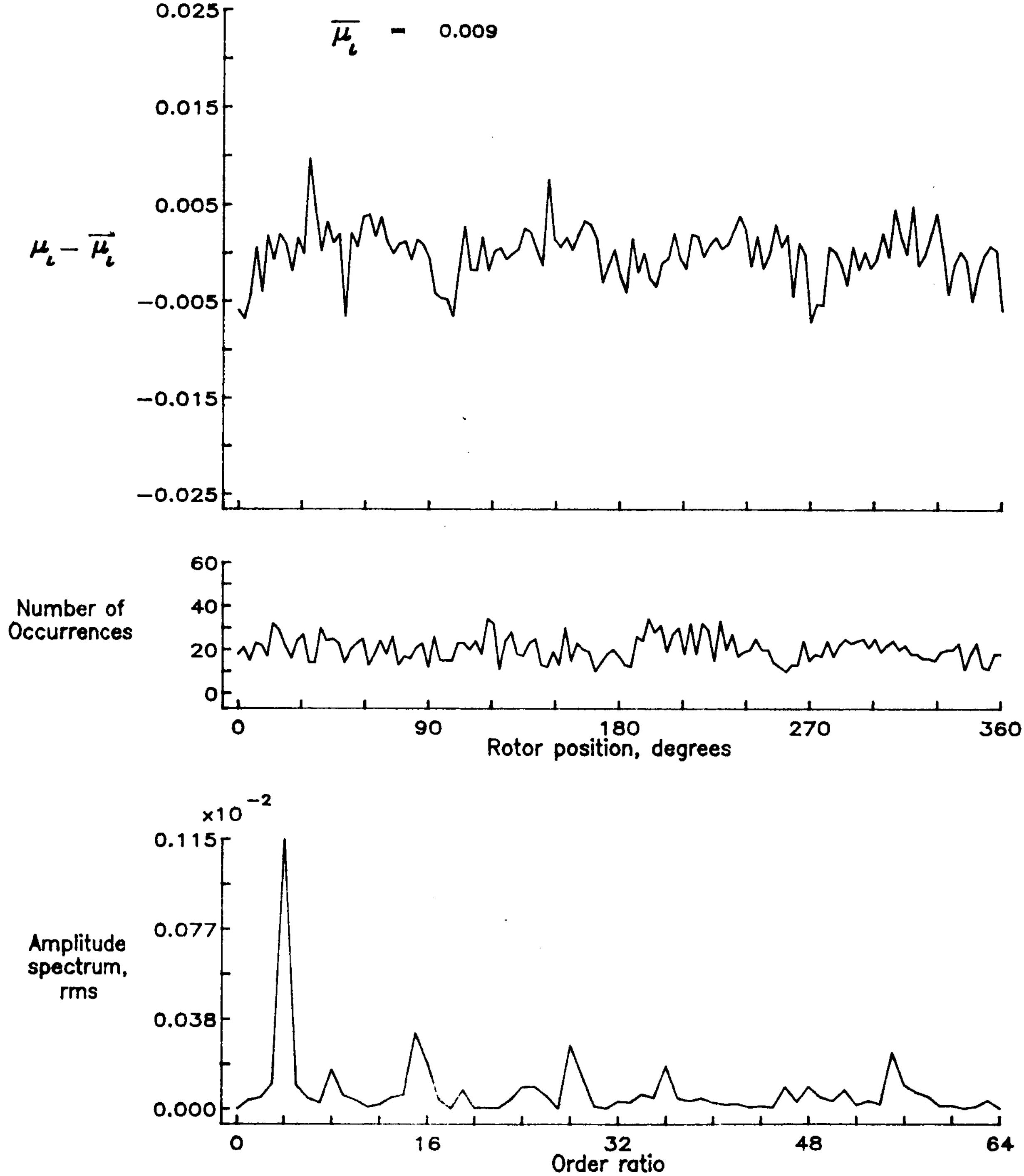


Figure 160.– Induced inflow velocity measured at 270 degrees and r/R of 1.02.

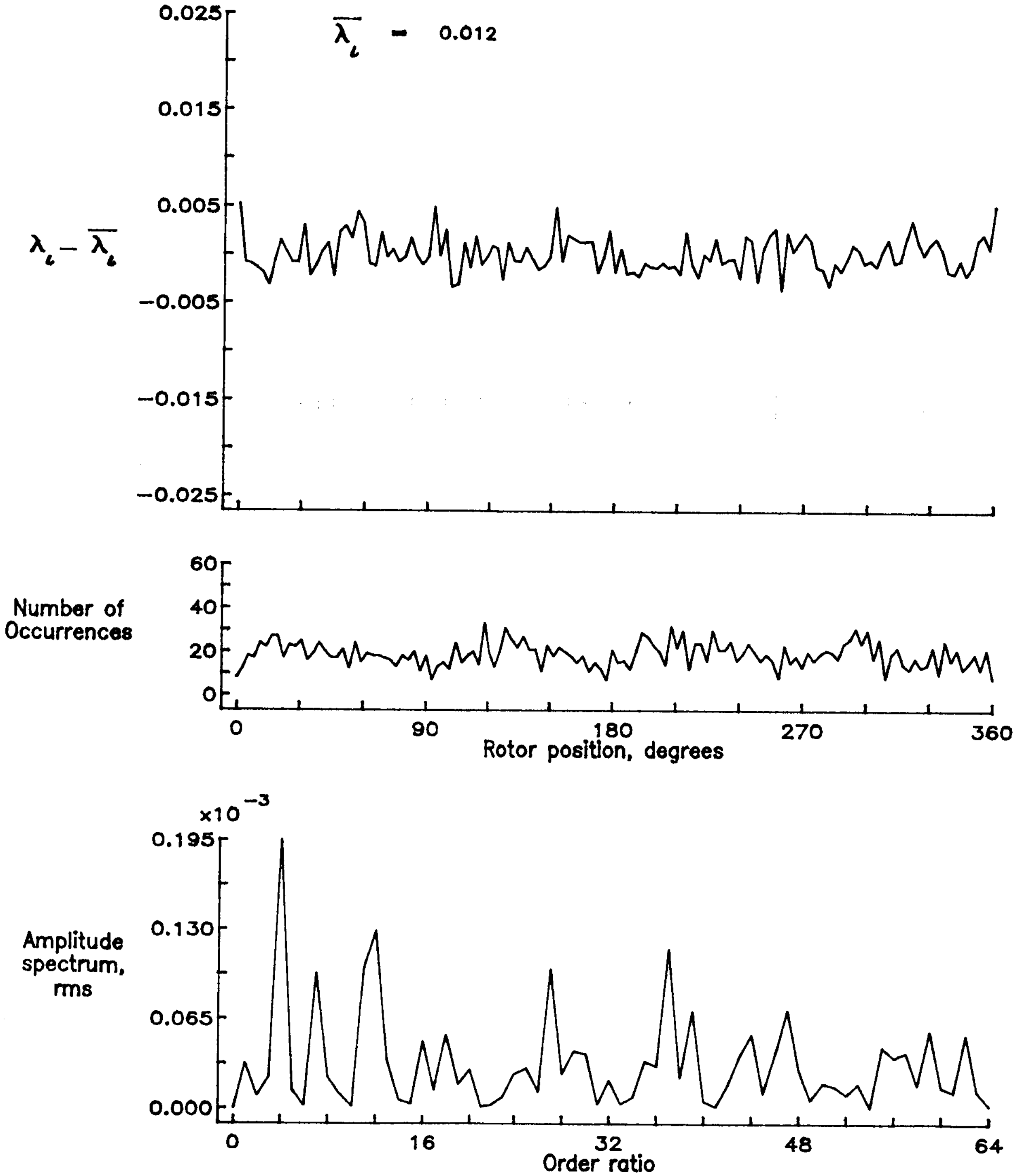


Figure 160.– Concluded.

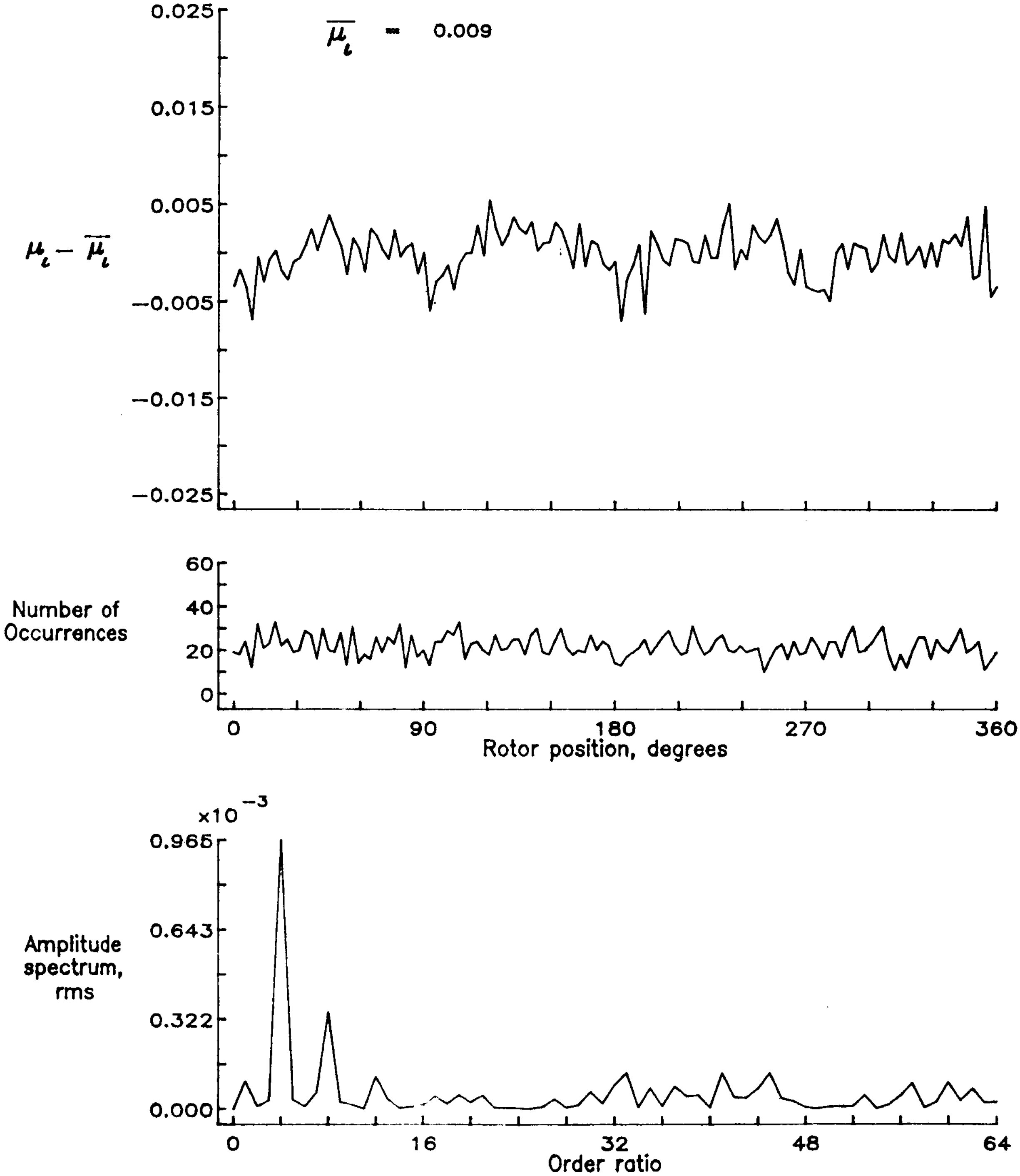


Figure 161.— Induced inflow velocity measured at 270 degrees and r/R of 1.04.

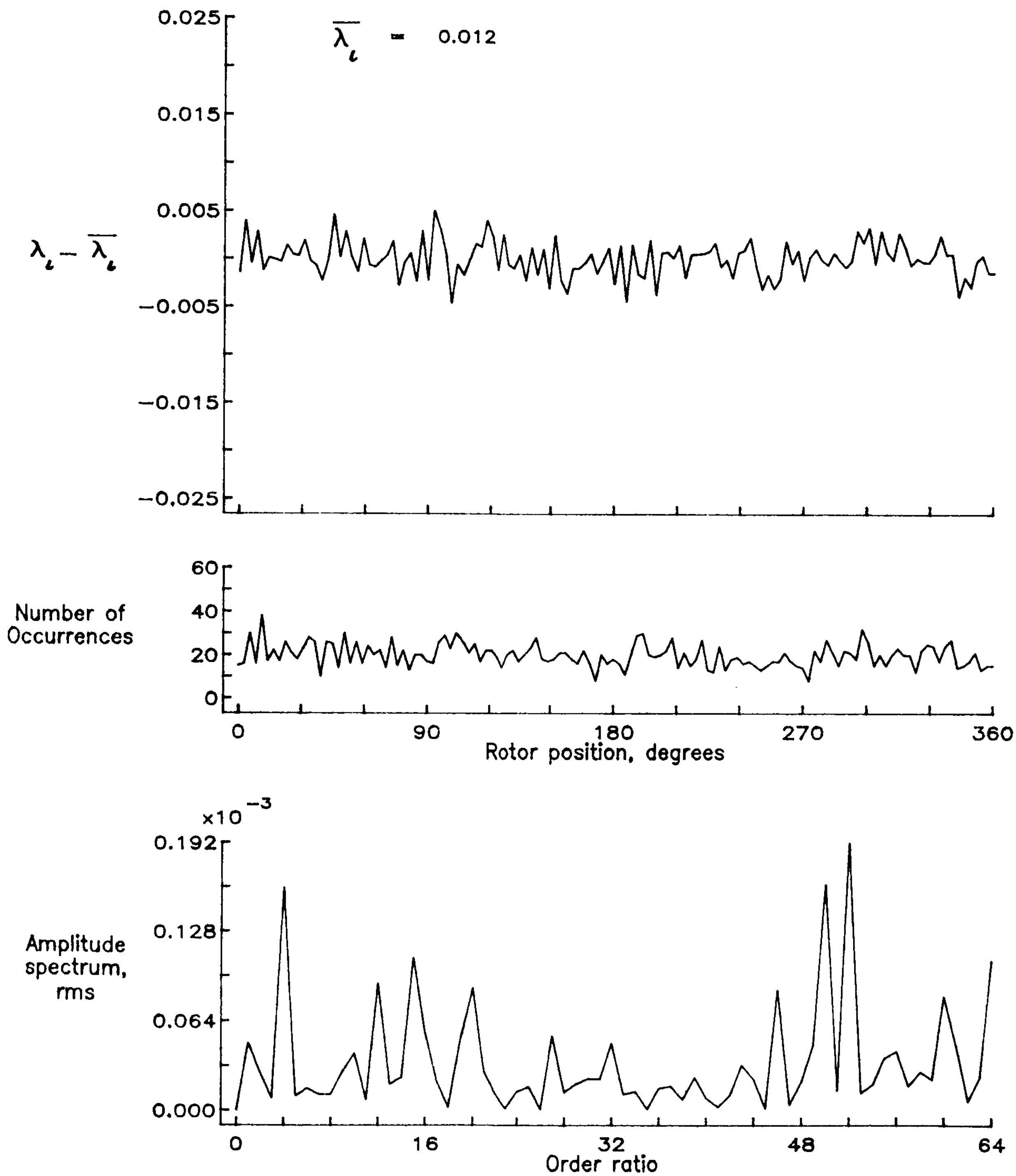


Figure 161.– Concluded.

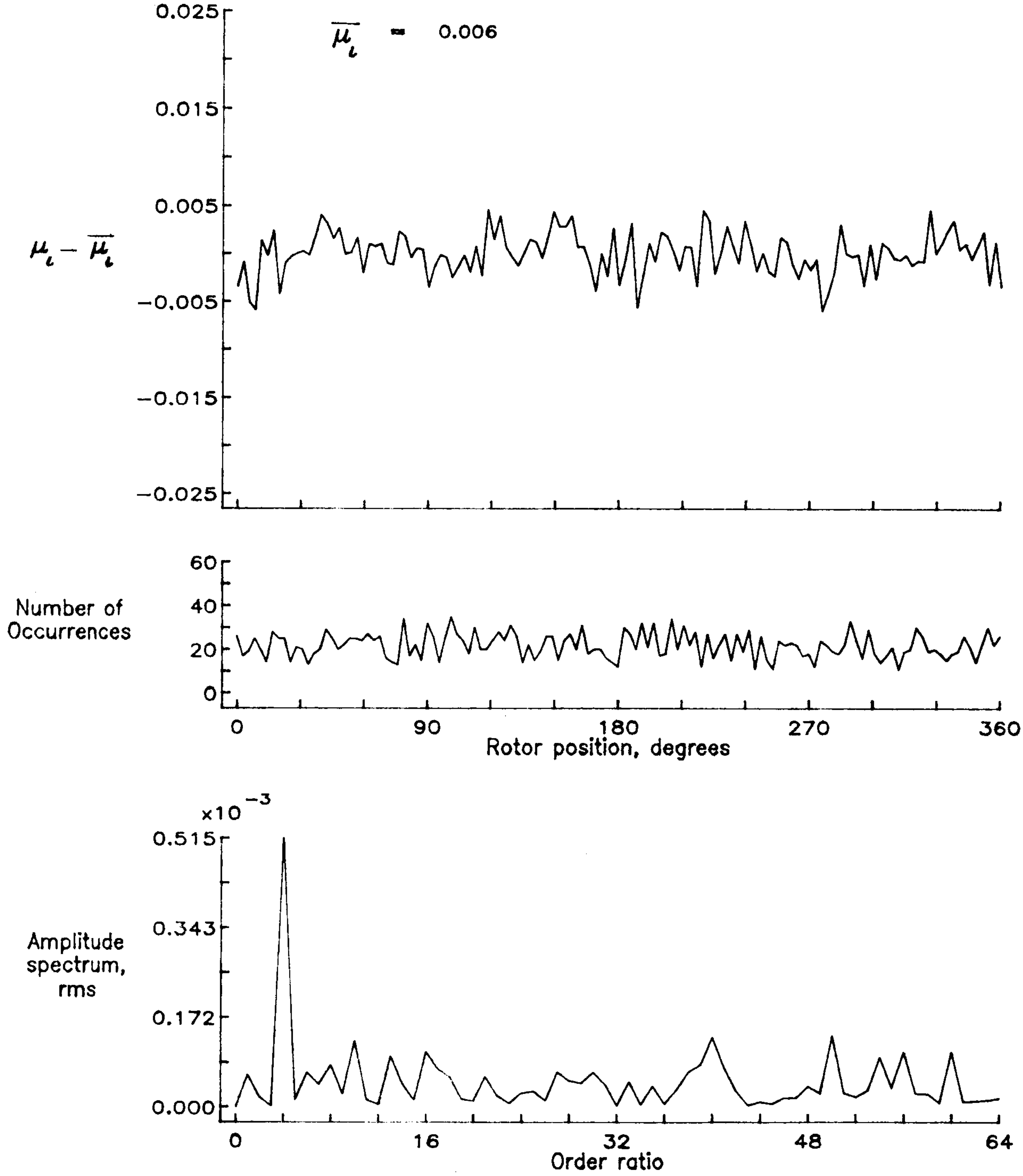
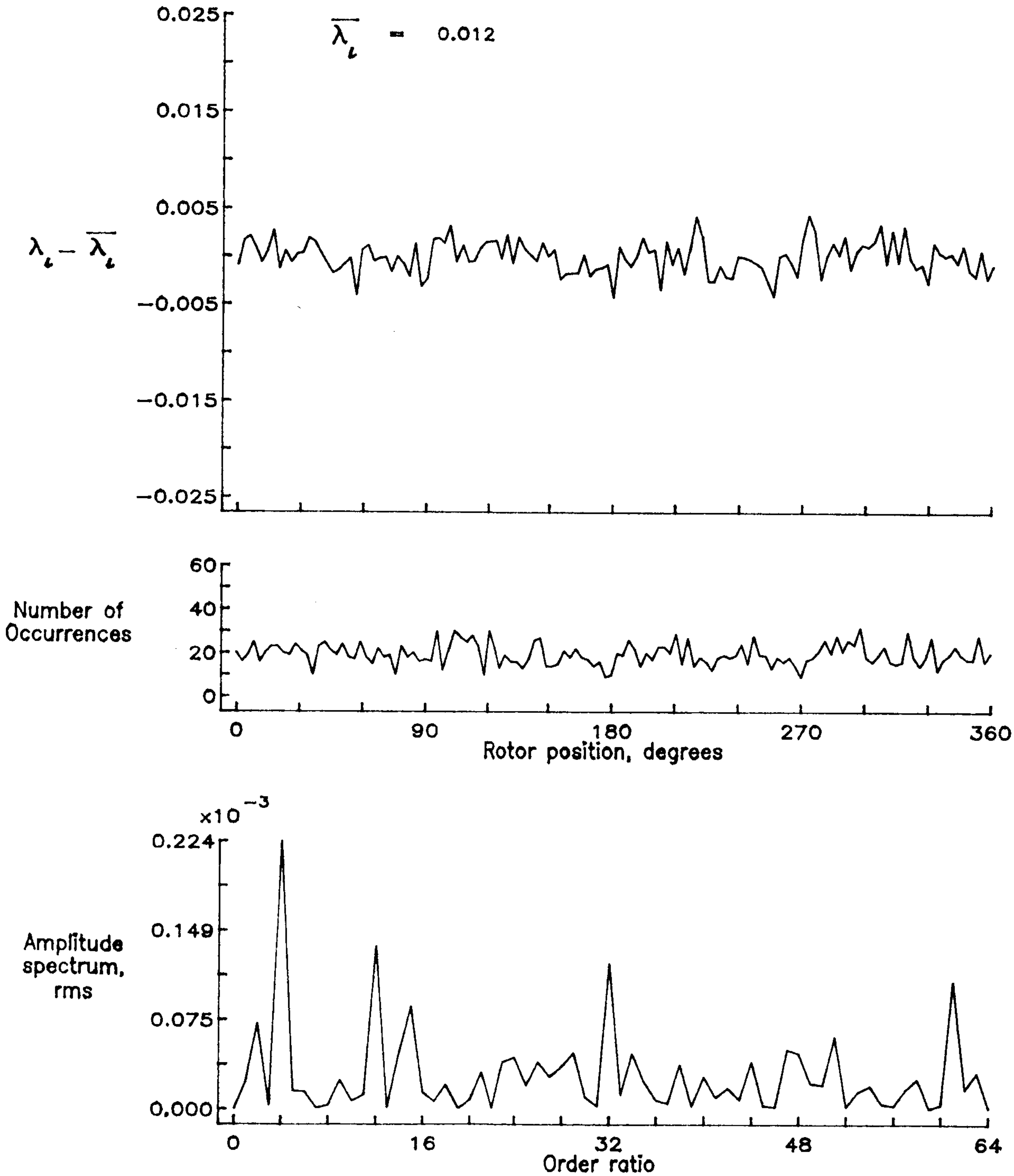


Figure 162.— Induced inflow velocity measured at 270 degrees and r/R of 1.10.



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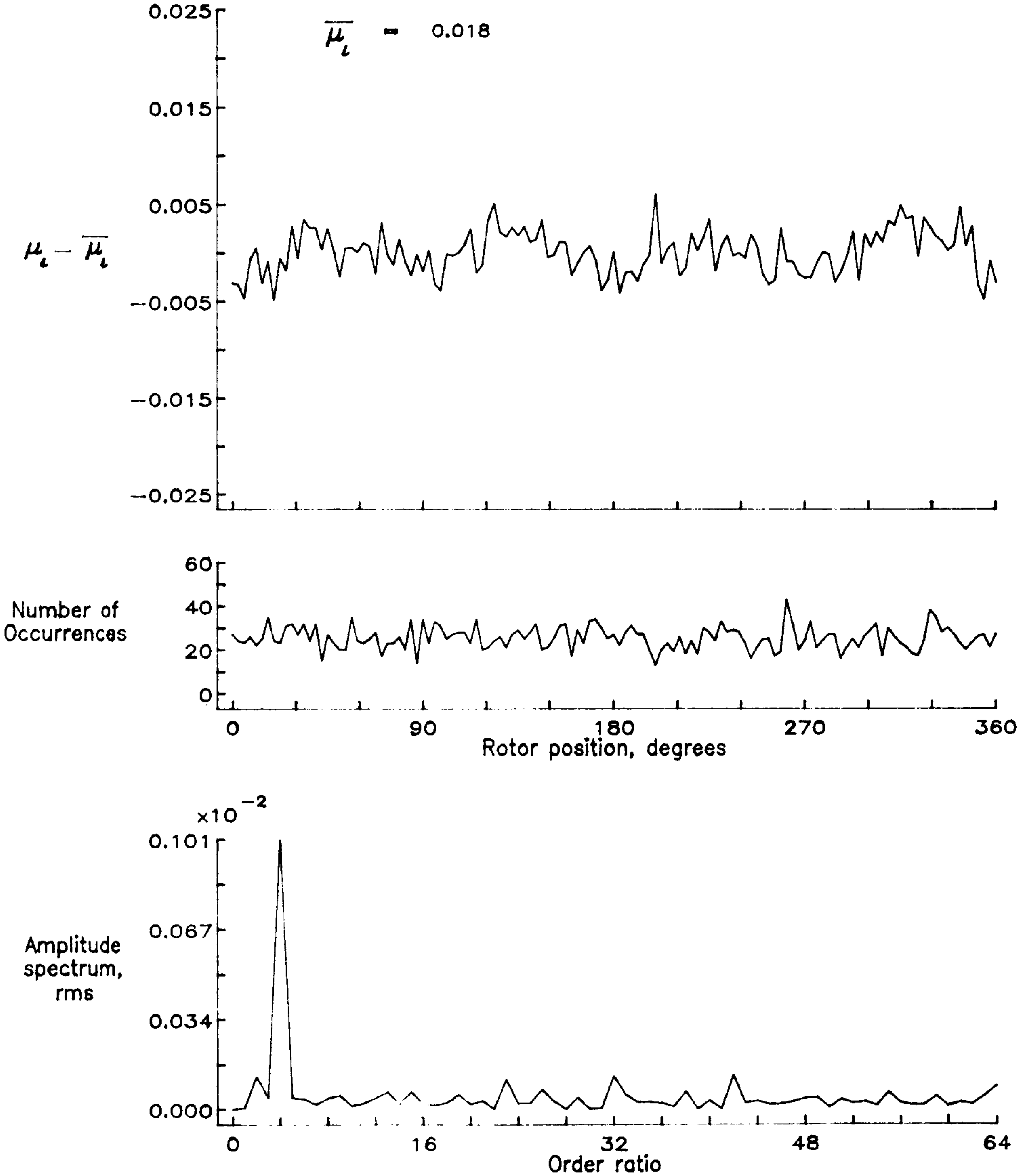


Figure 163.– Induced inflow velocity measured at 300 degrees and r/R of 0.20.

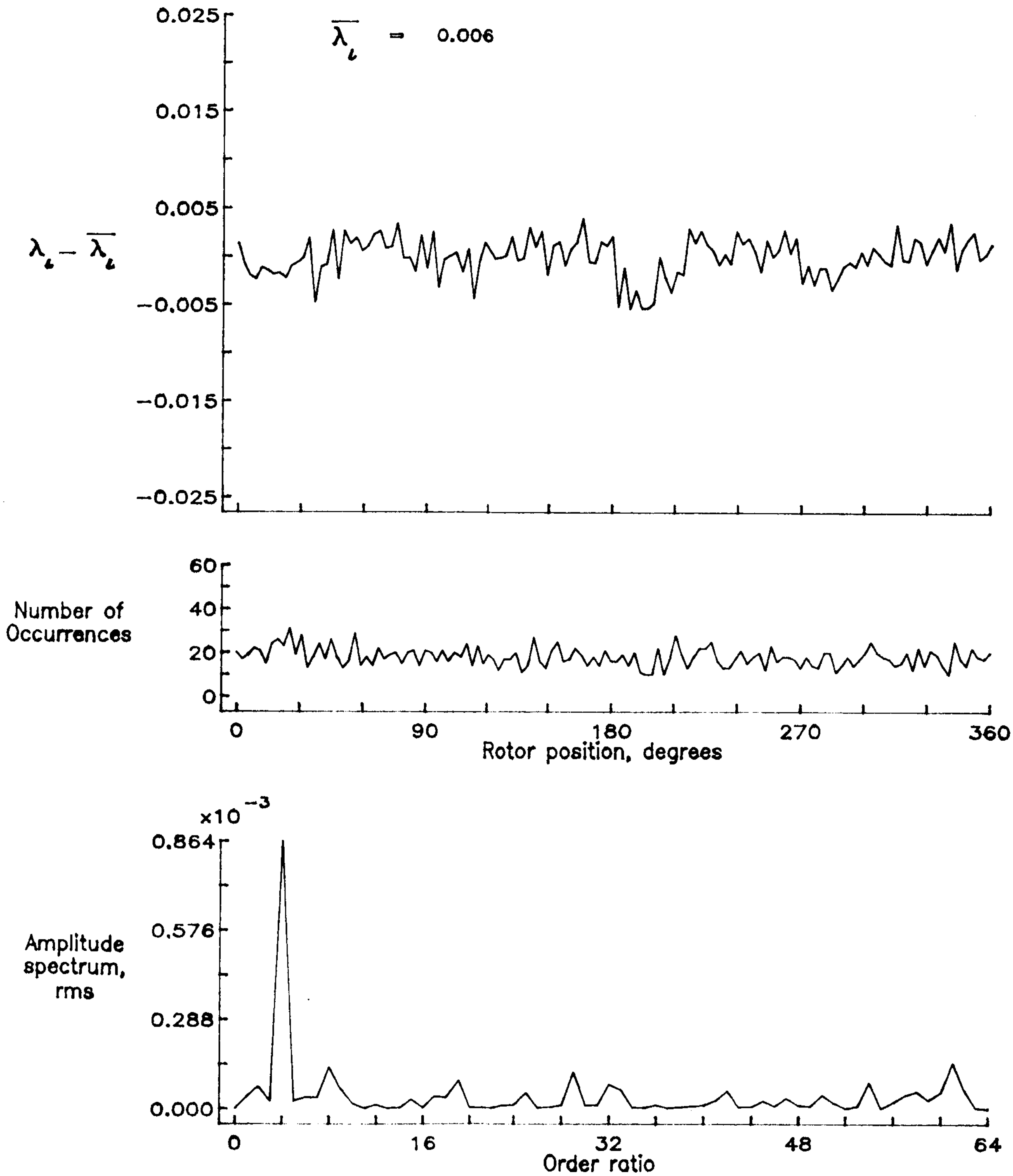


Figure 163.– Concluded.

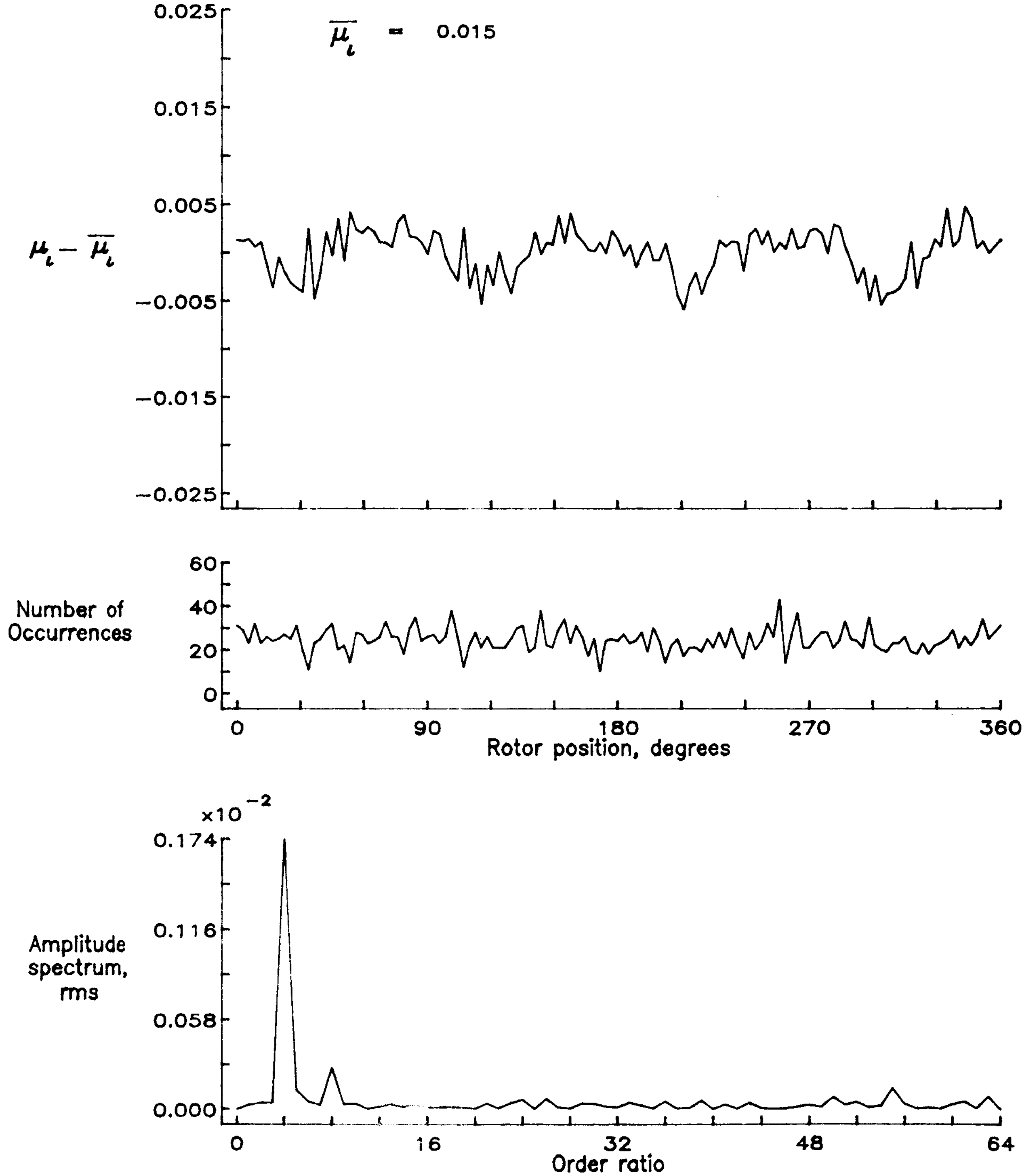


Figure 164.– Induced inflow velocity measured at 300 degrees and r/R of 0.40.

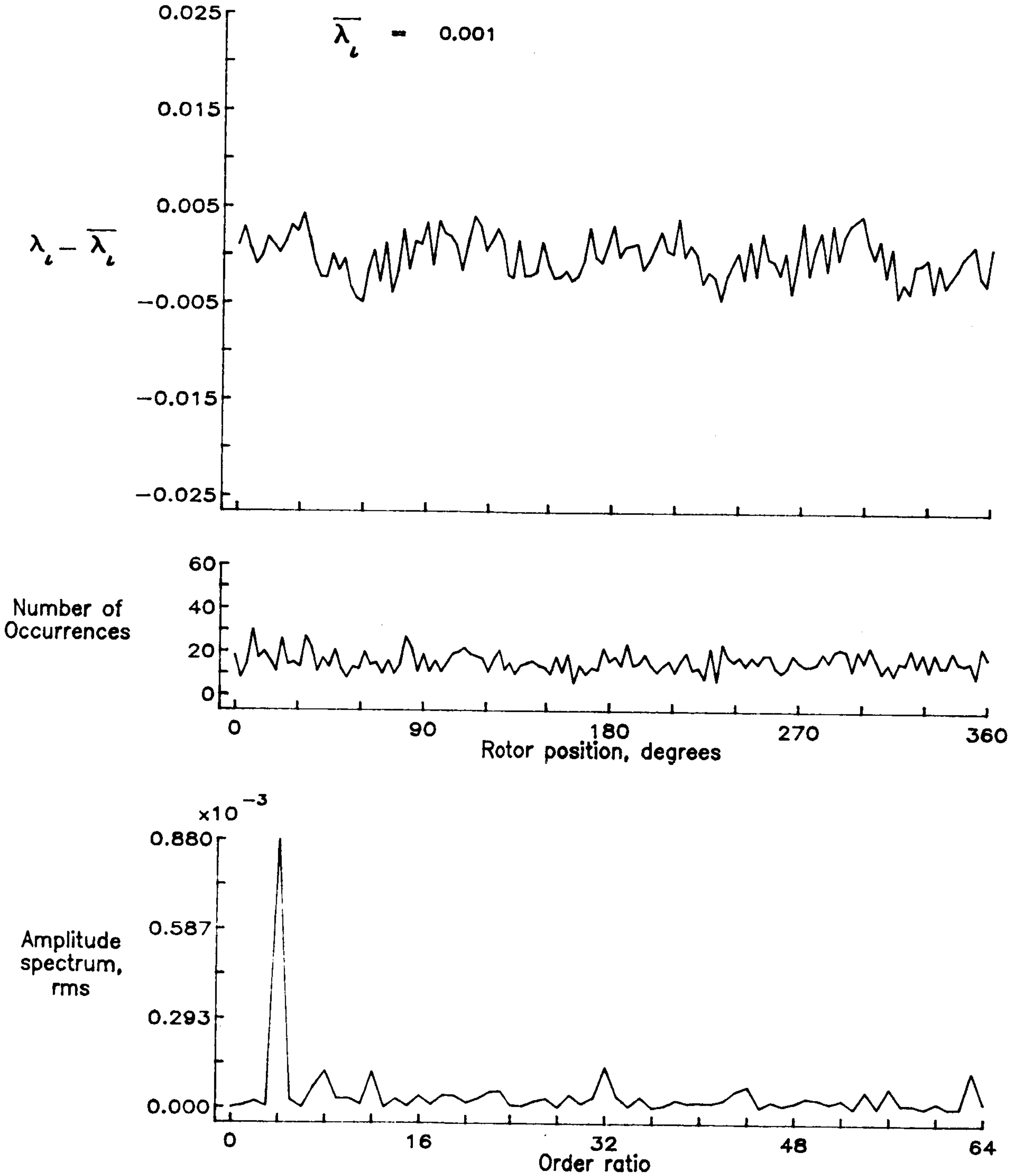


Figure 164.– Concluded.

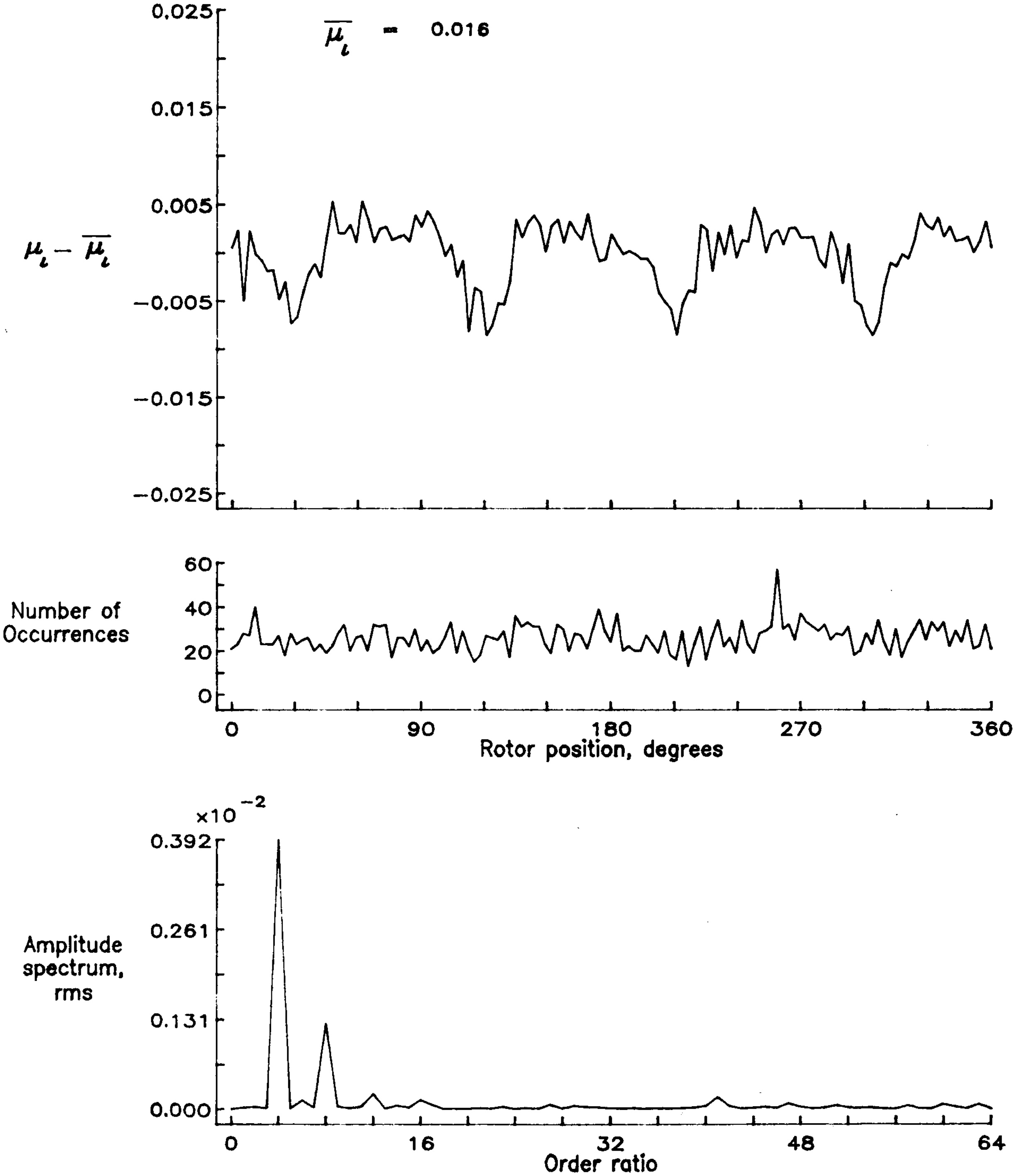


Figure 165.– Induced inflow velocity measured at 300 degrees and r/R of 0.50.

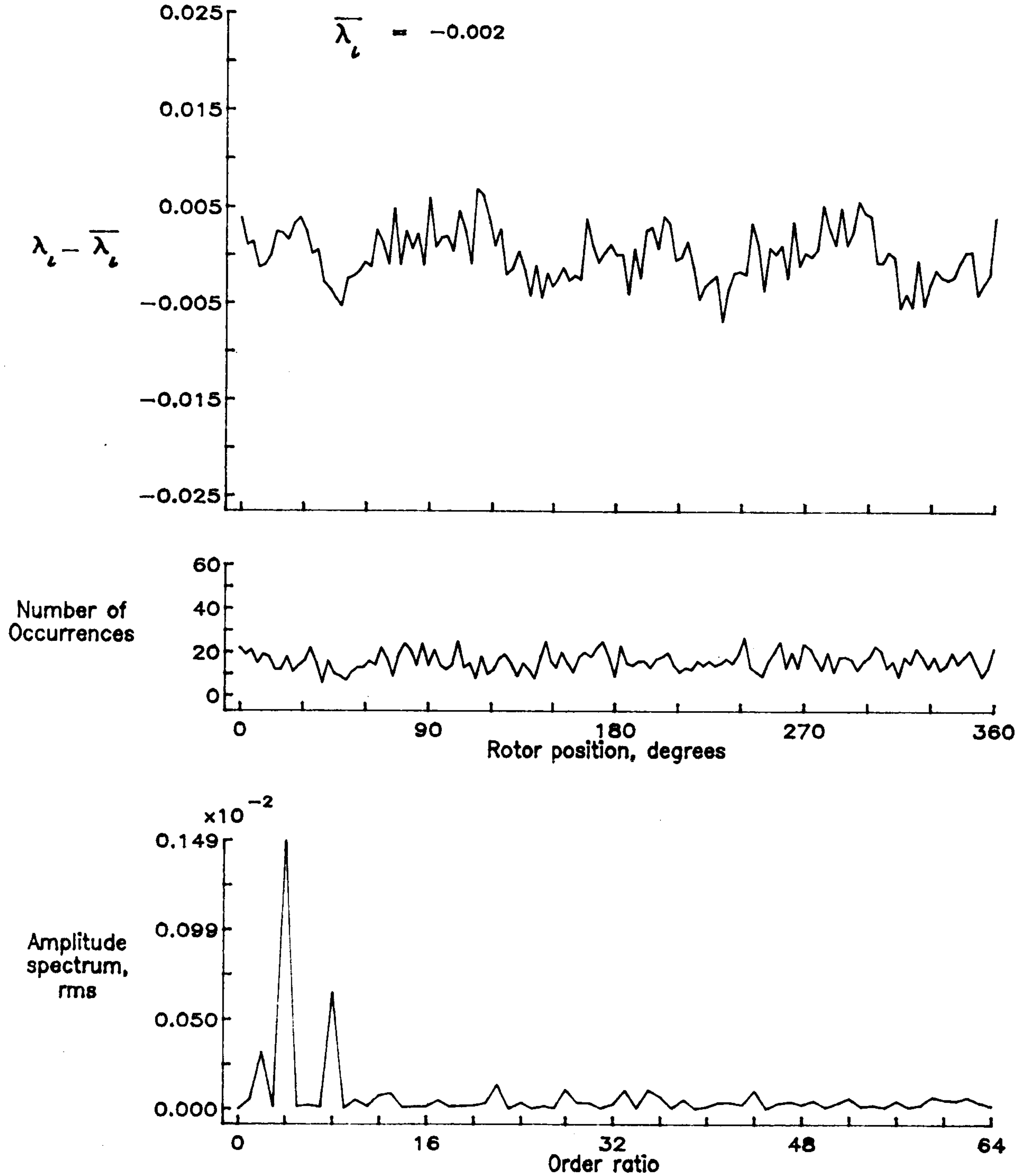


Figure 165.– Concluded.

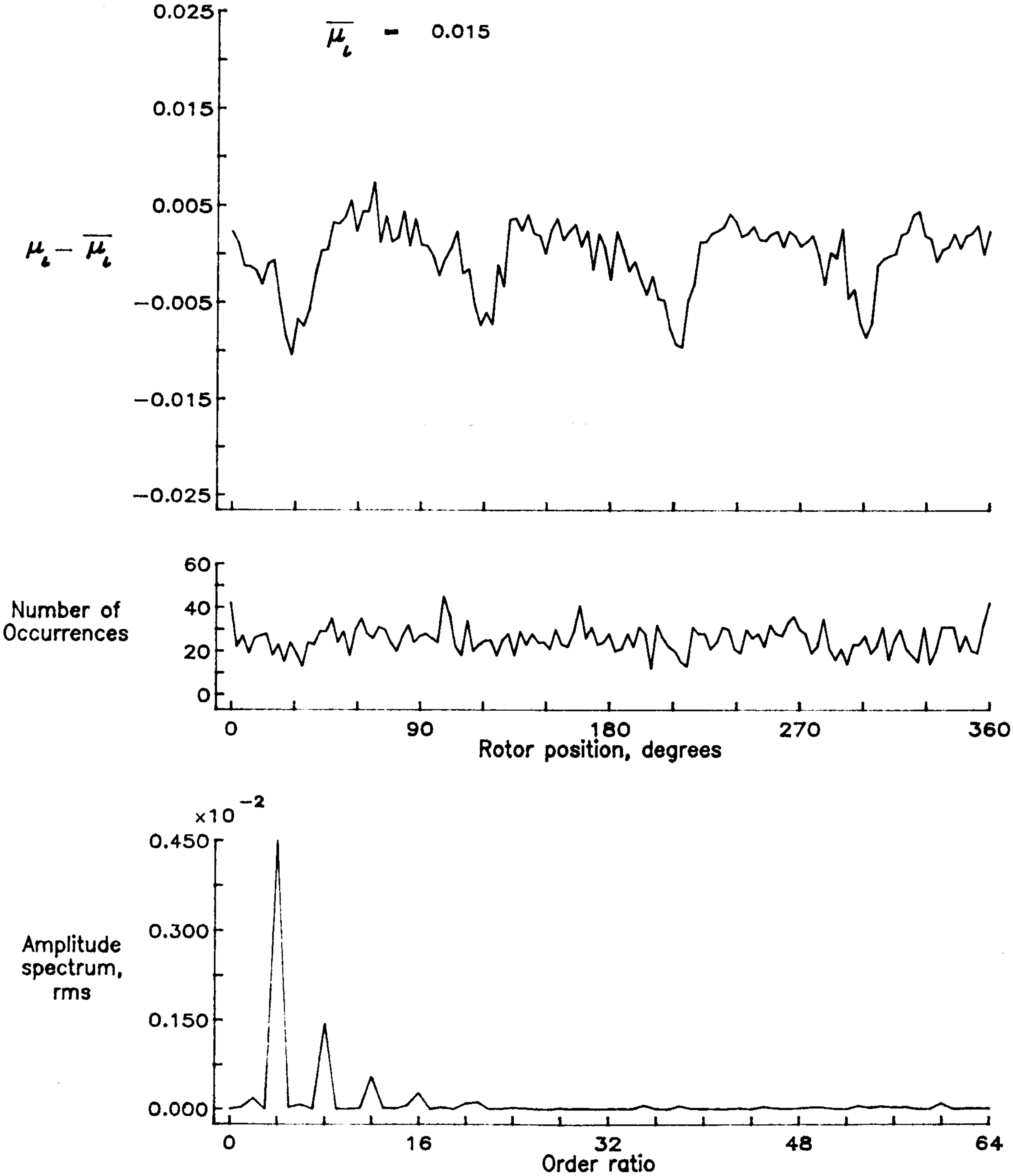


Figure 166.– Induced inflow velocity measured at 300 degrees and r/R of 0.60.

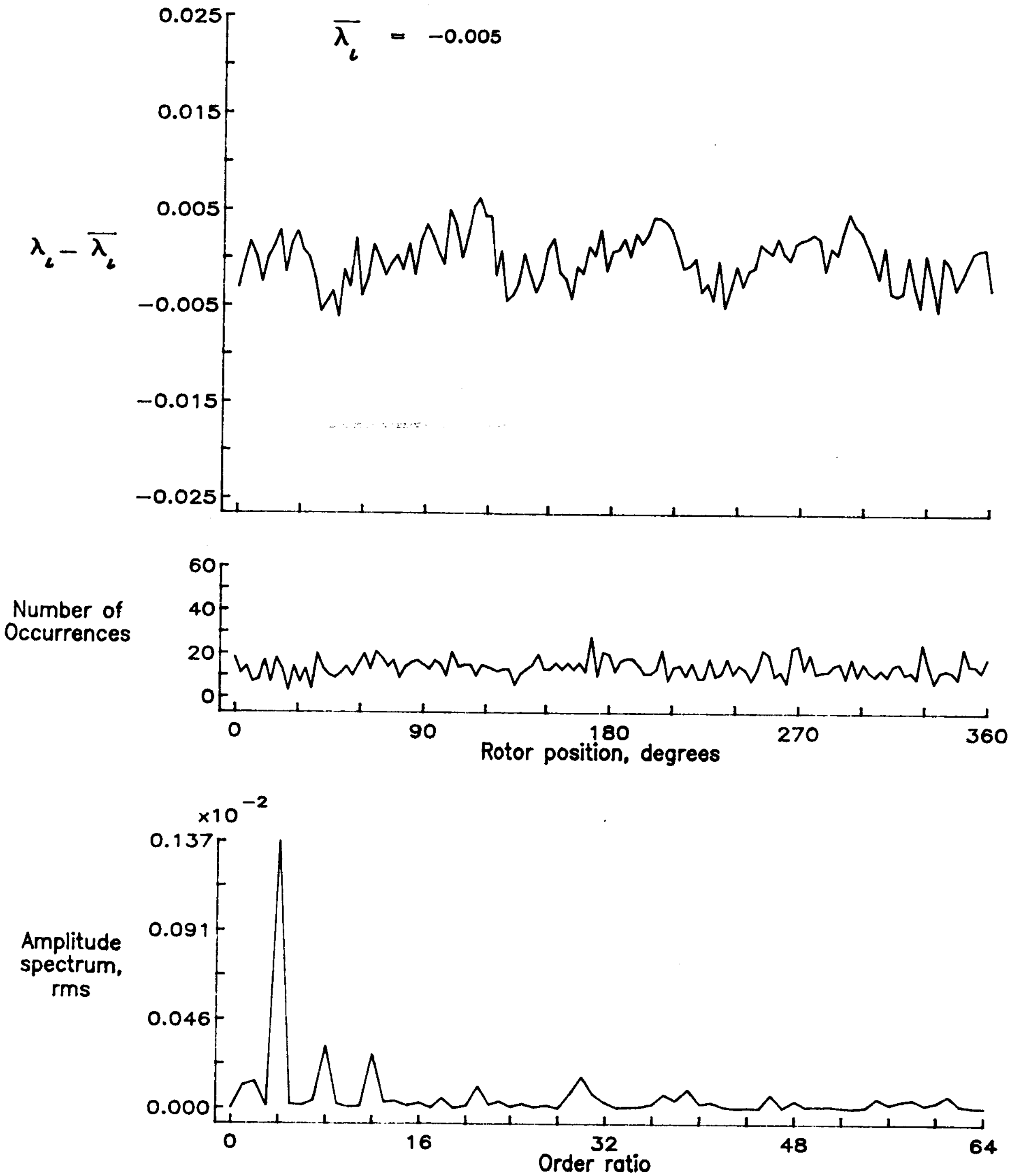


Figure 166.– Concluded.

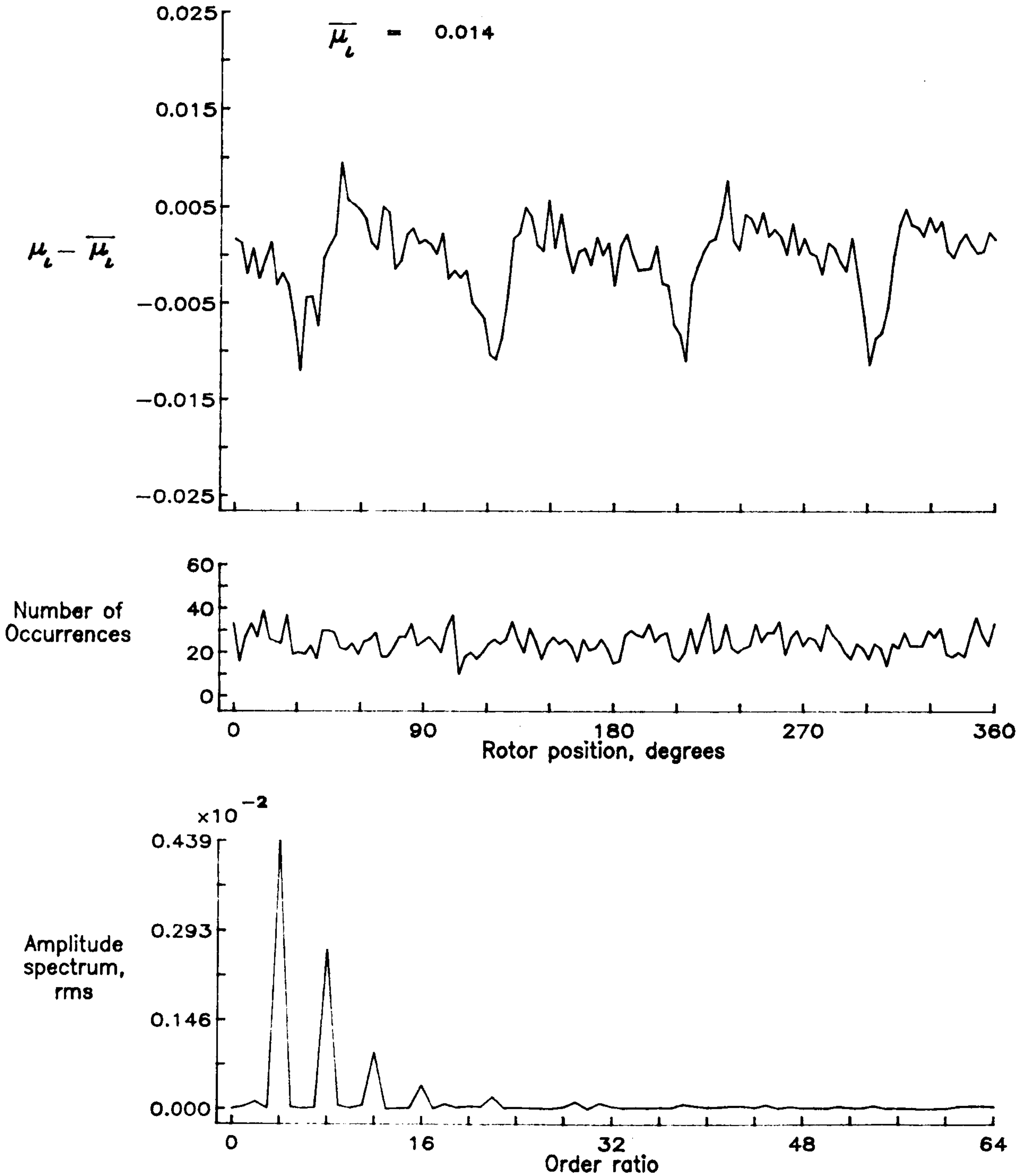


Figure 167.– Induced inflow velocity measured at 300 degrees and r/R of 0.70.

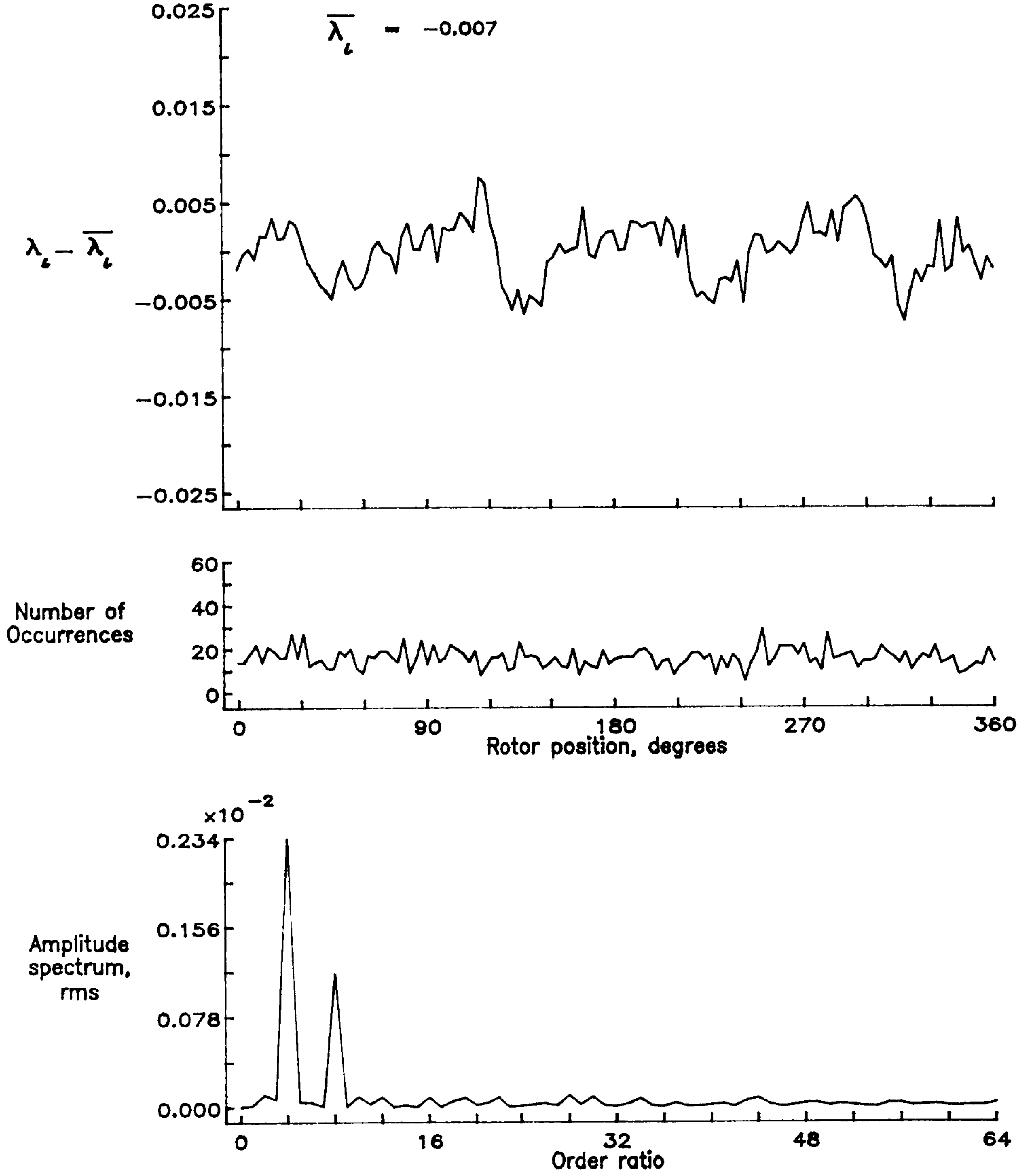


Figure 167.– Concluded.

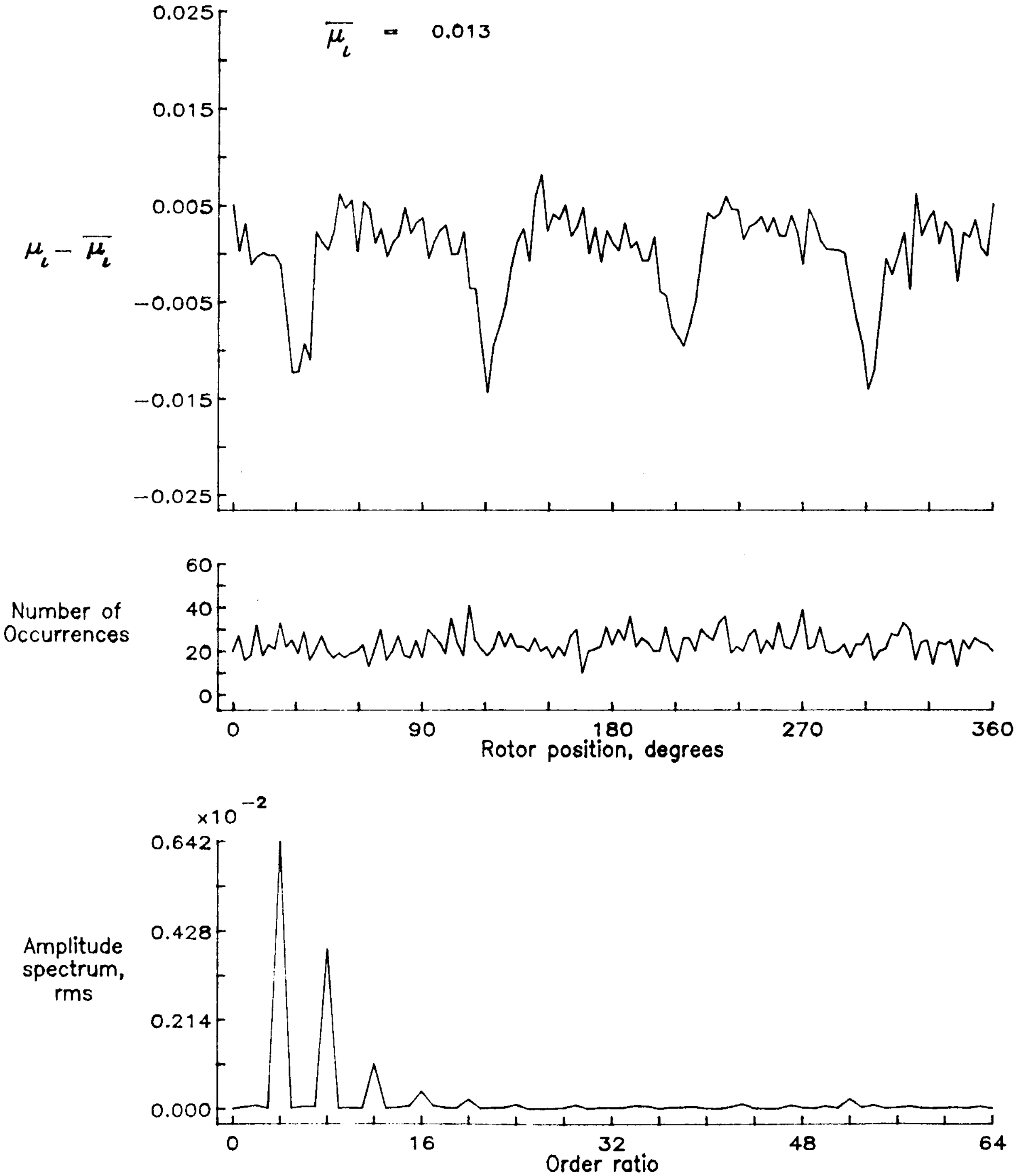
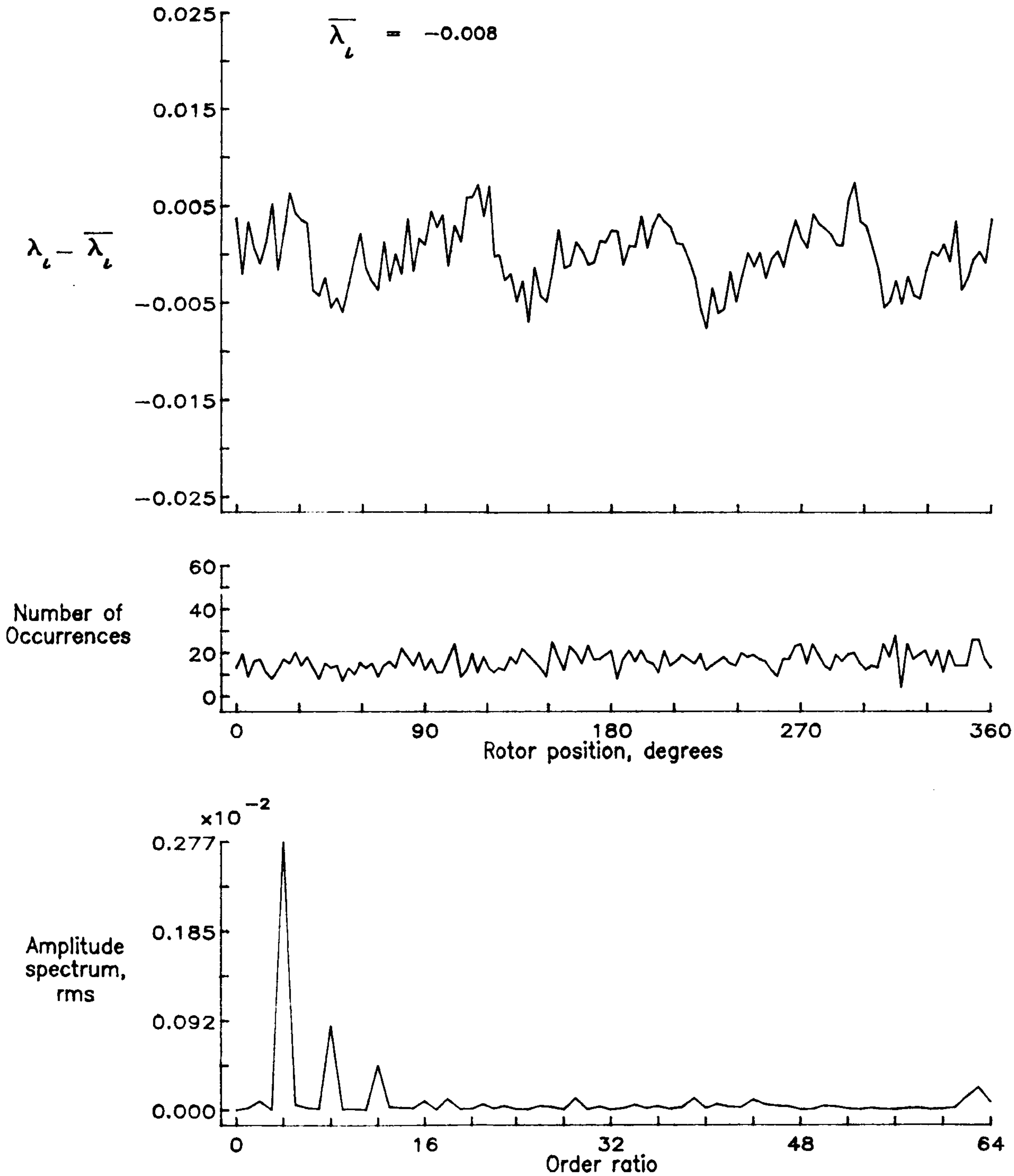


Figure 168.– Induced inflow velocity measured at 300 degrees and r/R of 0.74.



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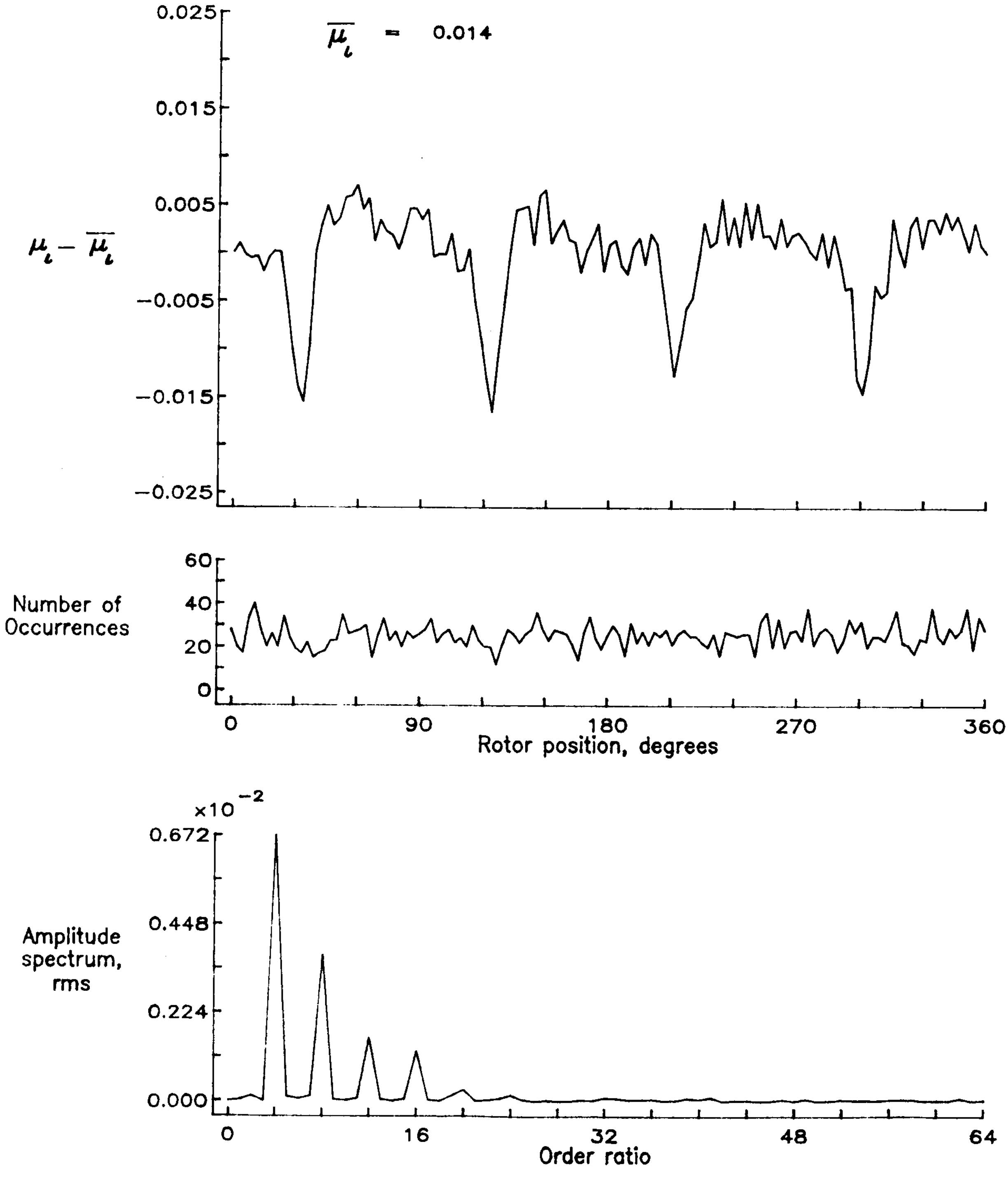
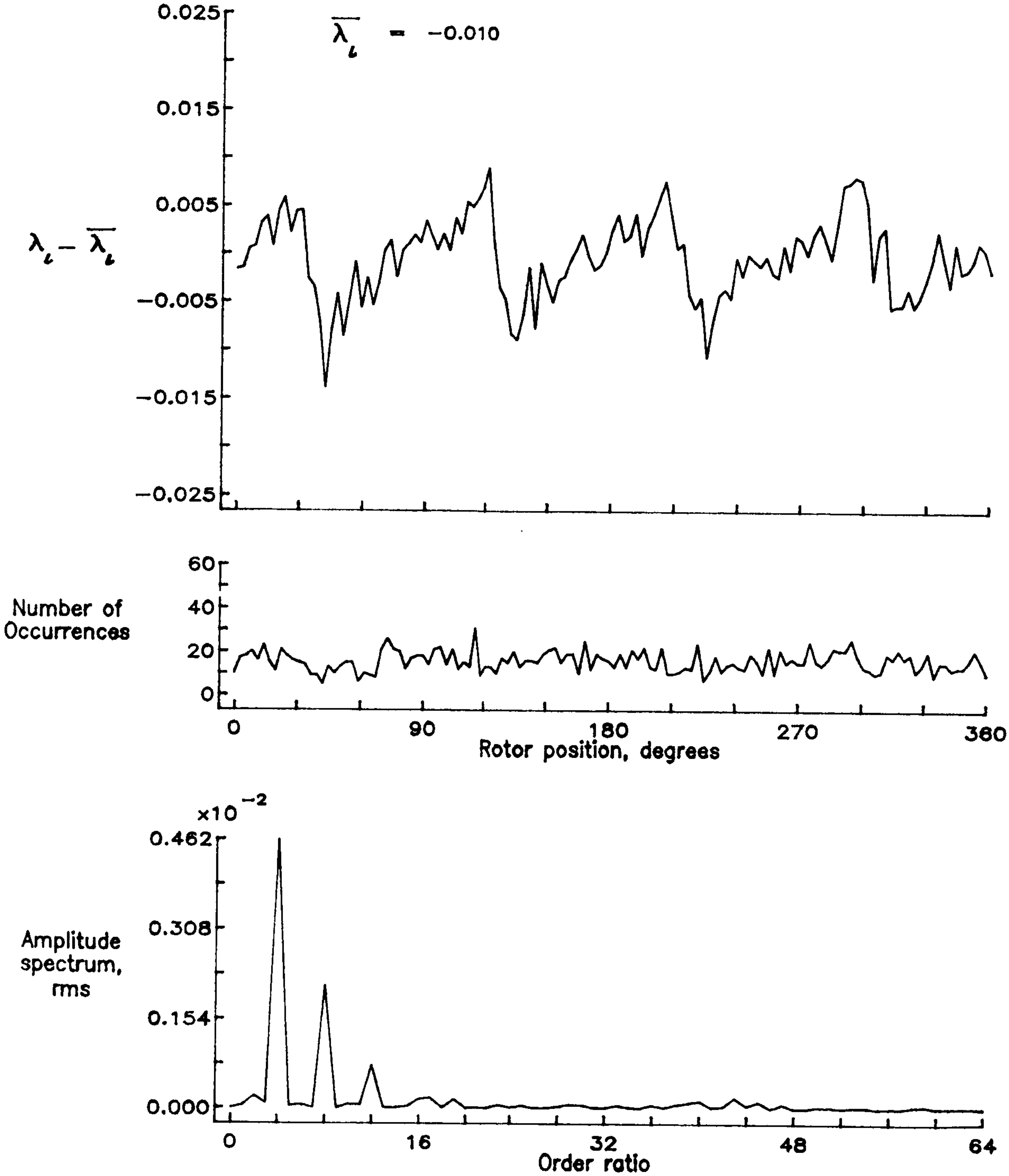


Figure 169.– Induced inflow velocity measured at 300 degrees and r/R of 0.78.



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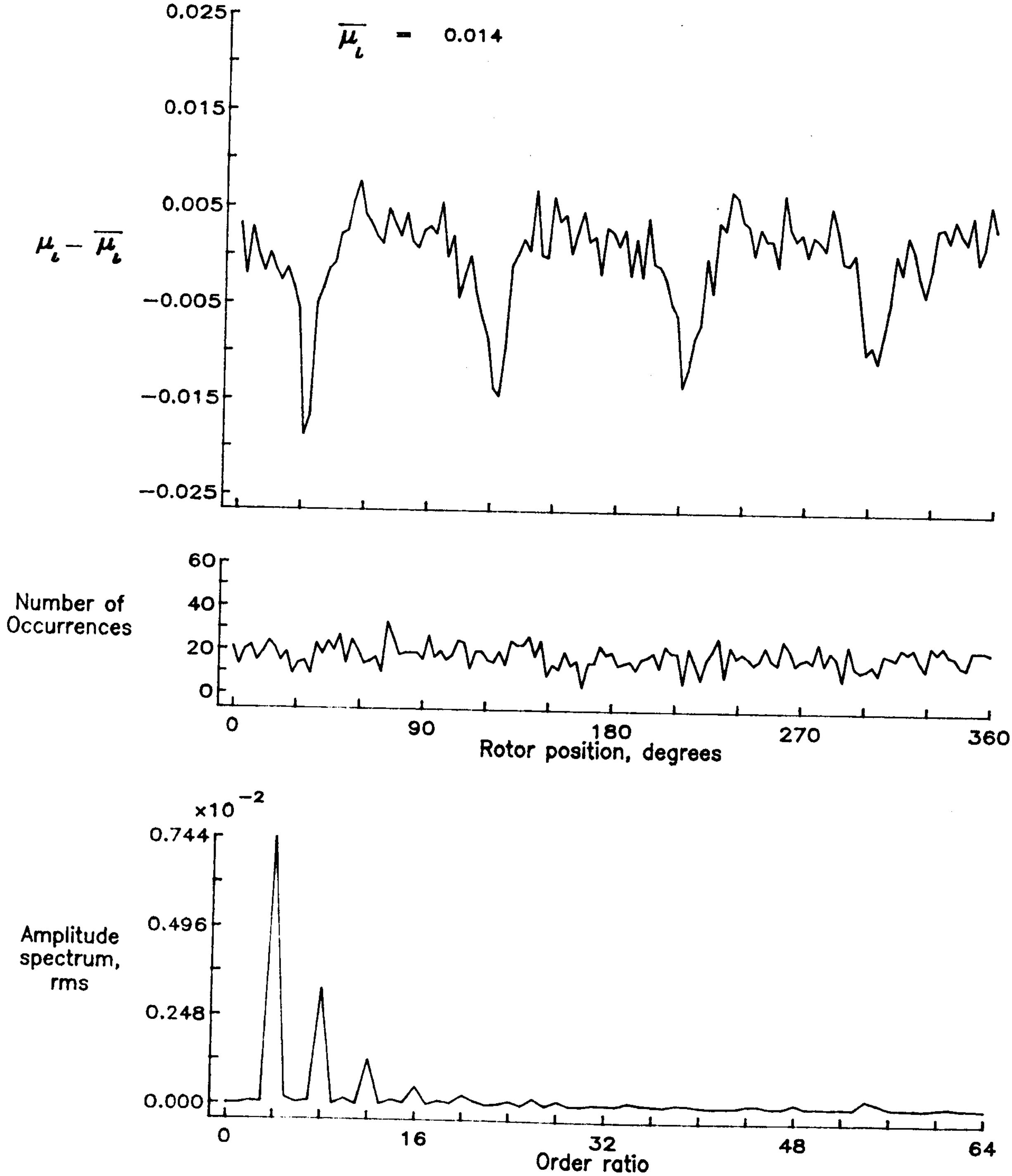
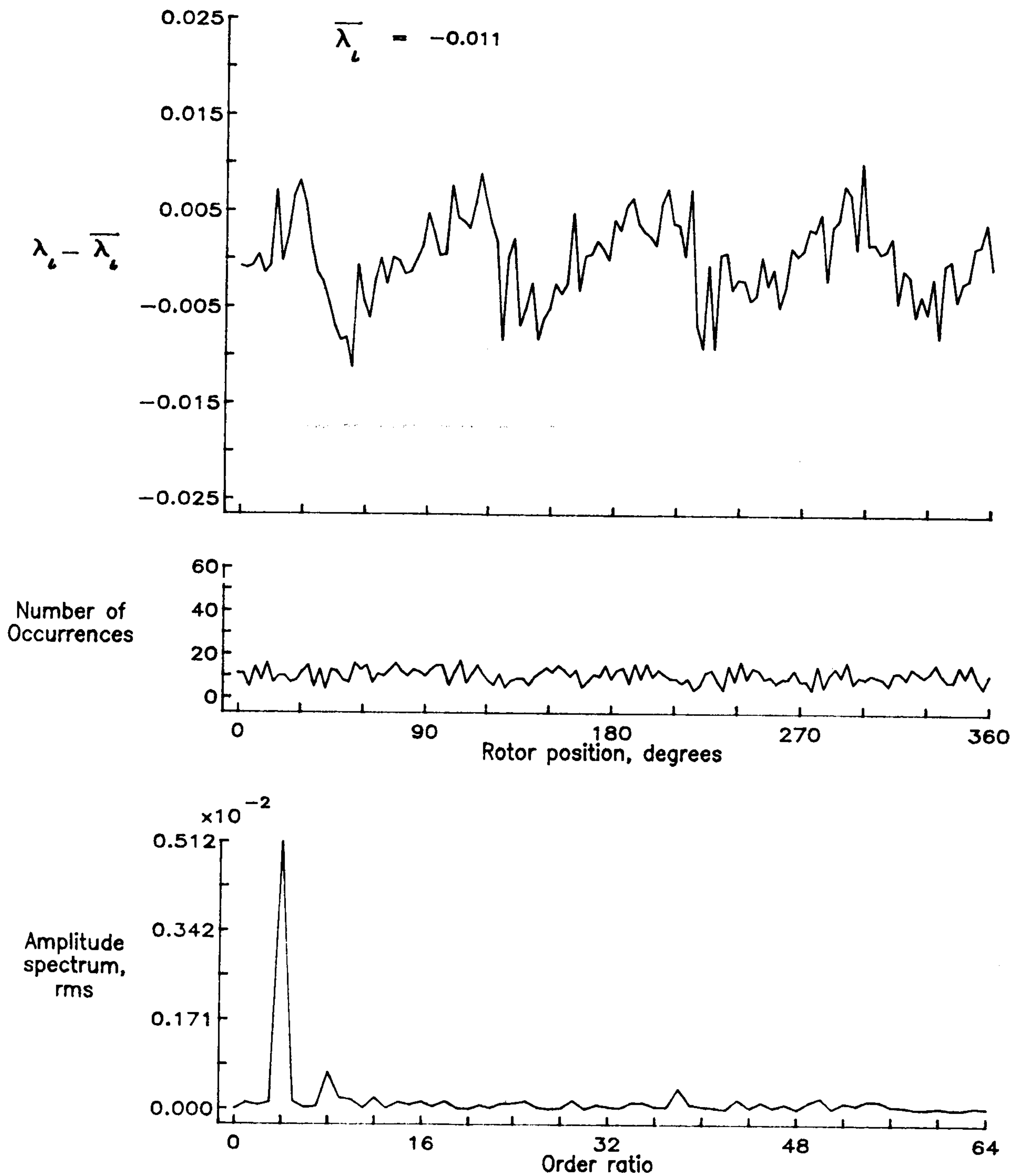


Figure 170.– Induced inflow velocity measured at 300 degrees and r/R of 0.82.



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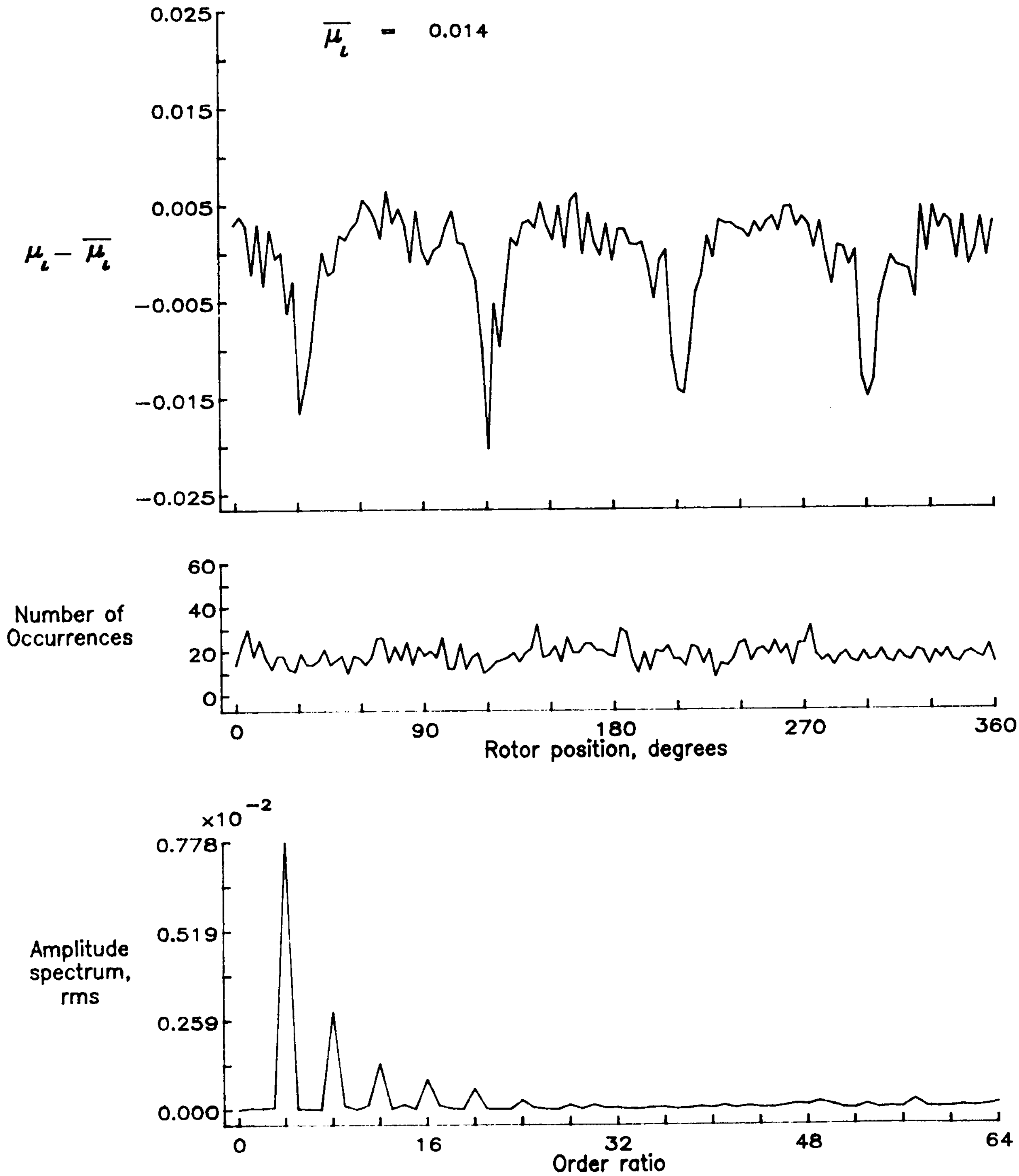


Figure 171.– Induced inflow velocity measured at 300 degrees and r/R of 0.86.

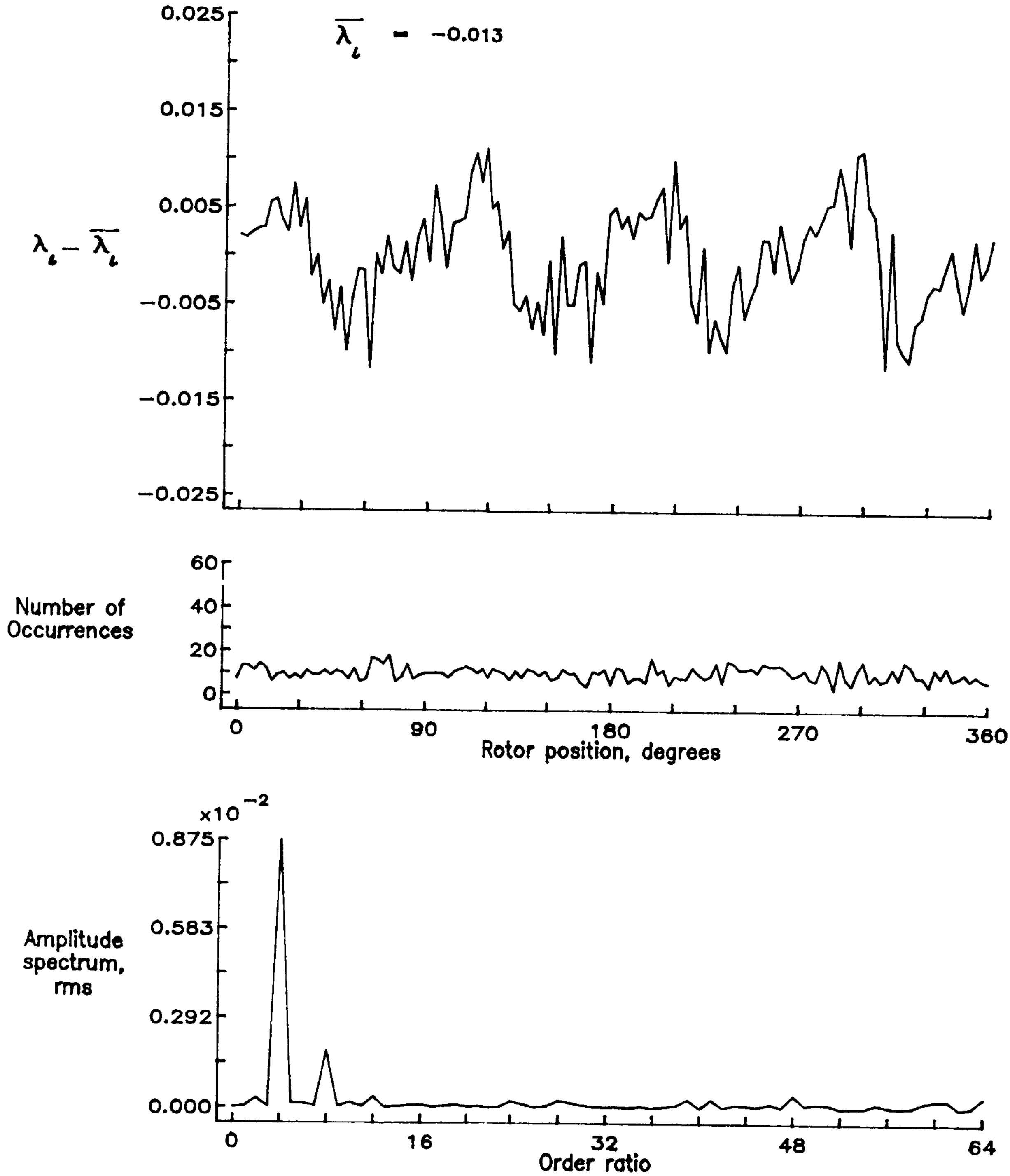


Figure 171.– Concluded.

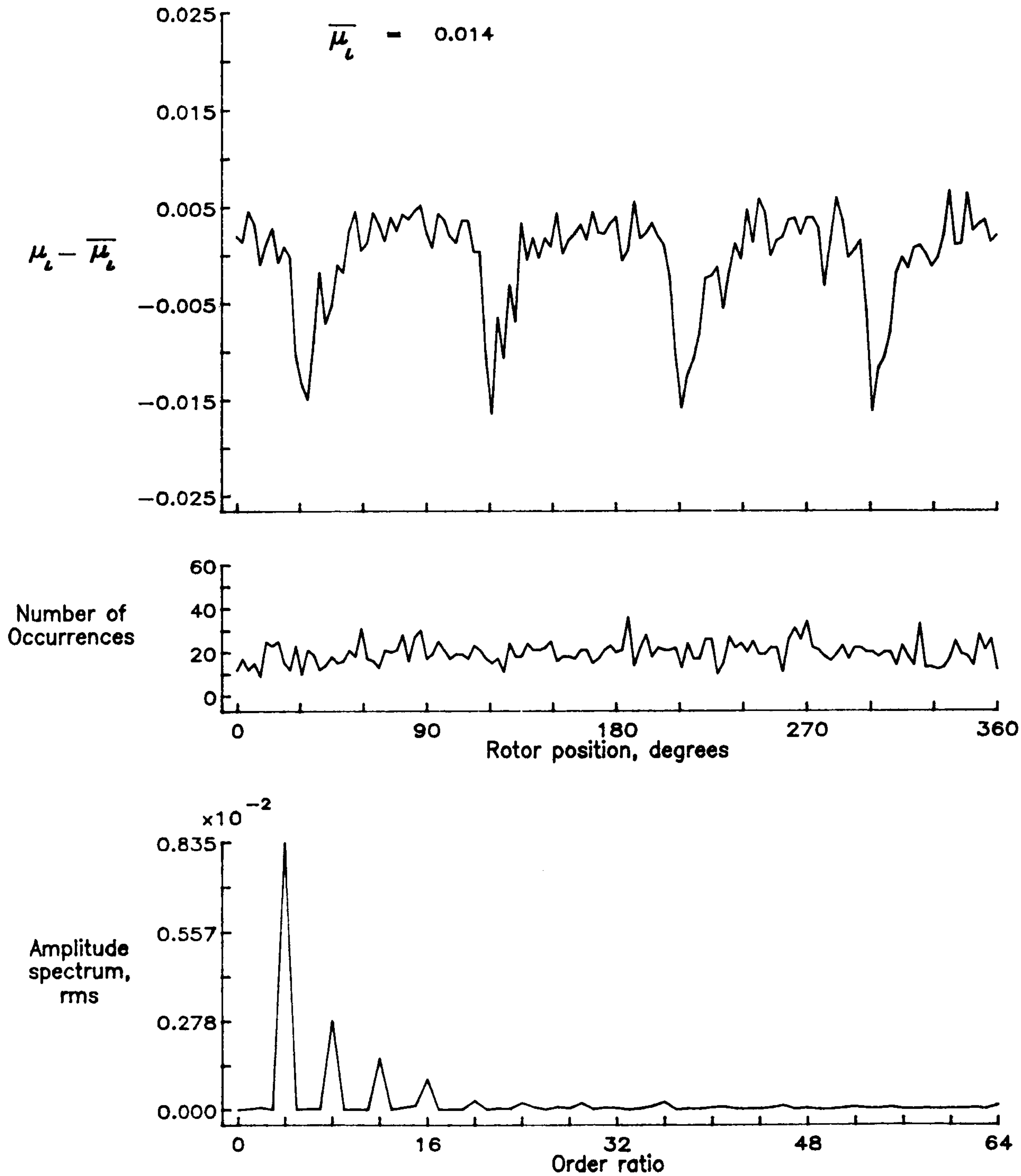
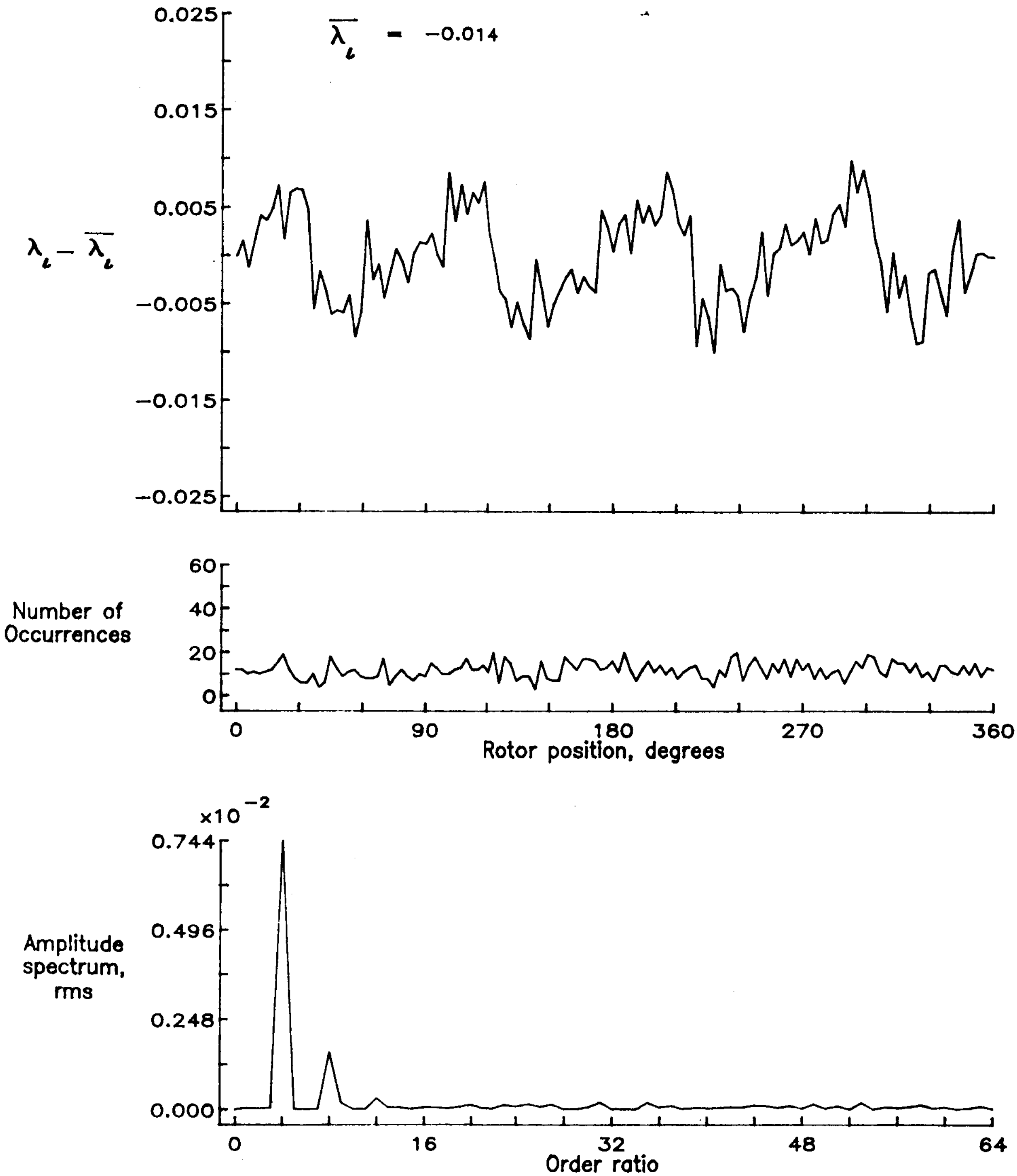


Figure 172.– Induced inflow velocity measured at 300 degrees and r/R of 0.90.



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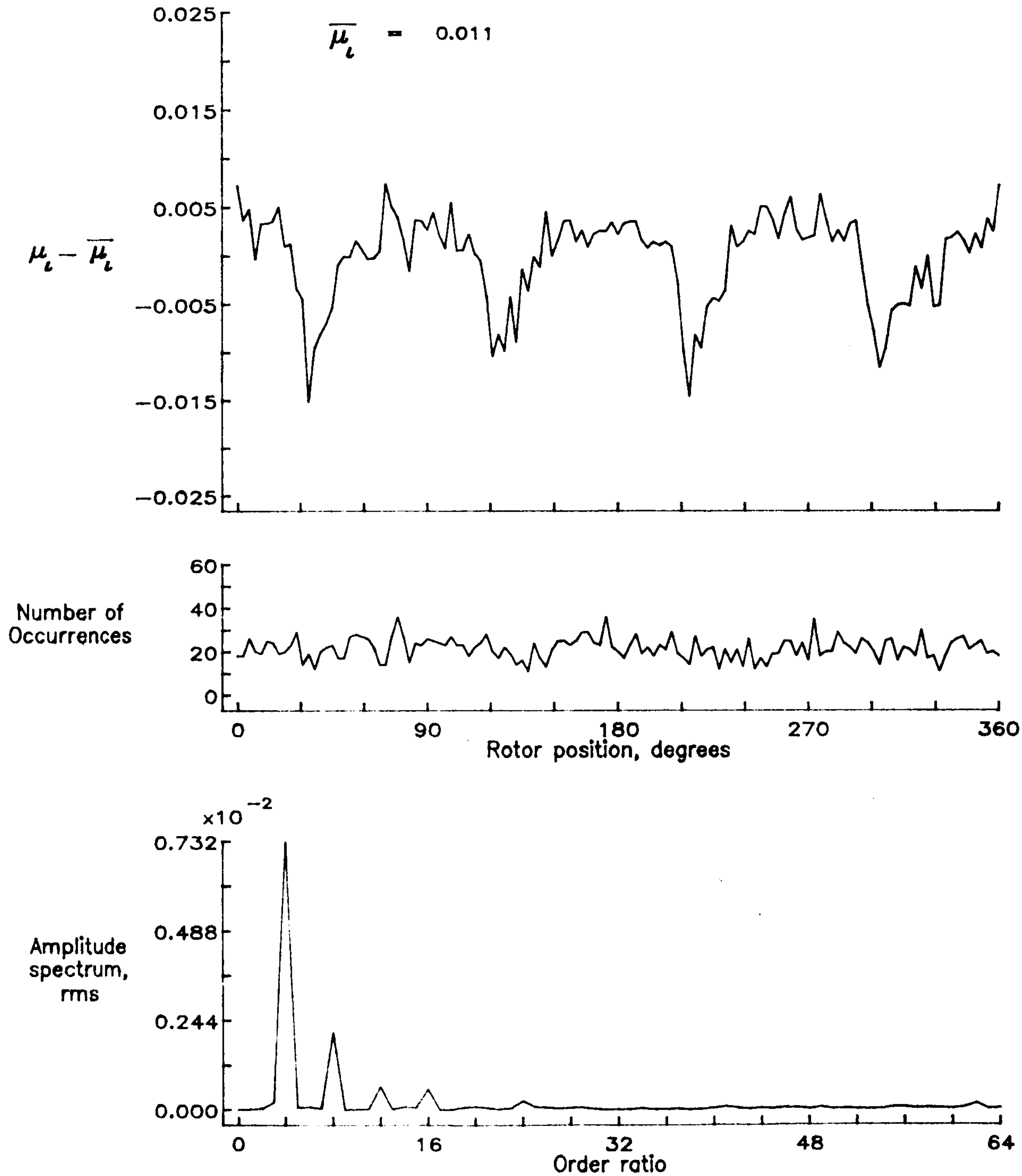
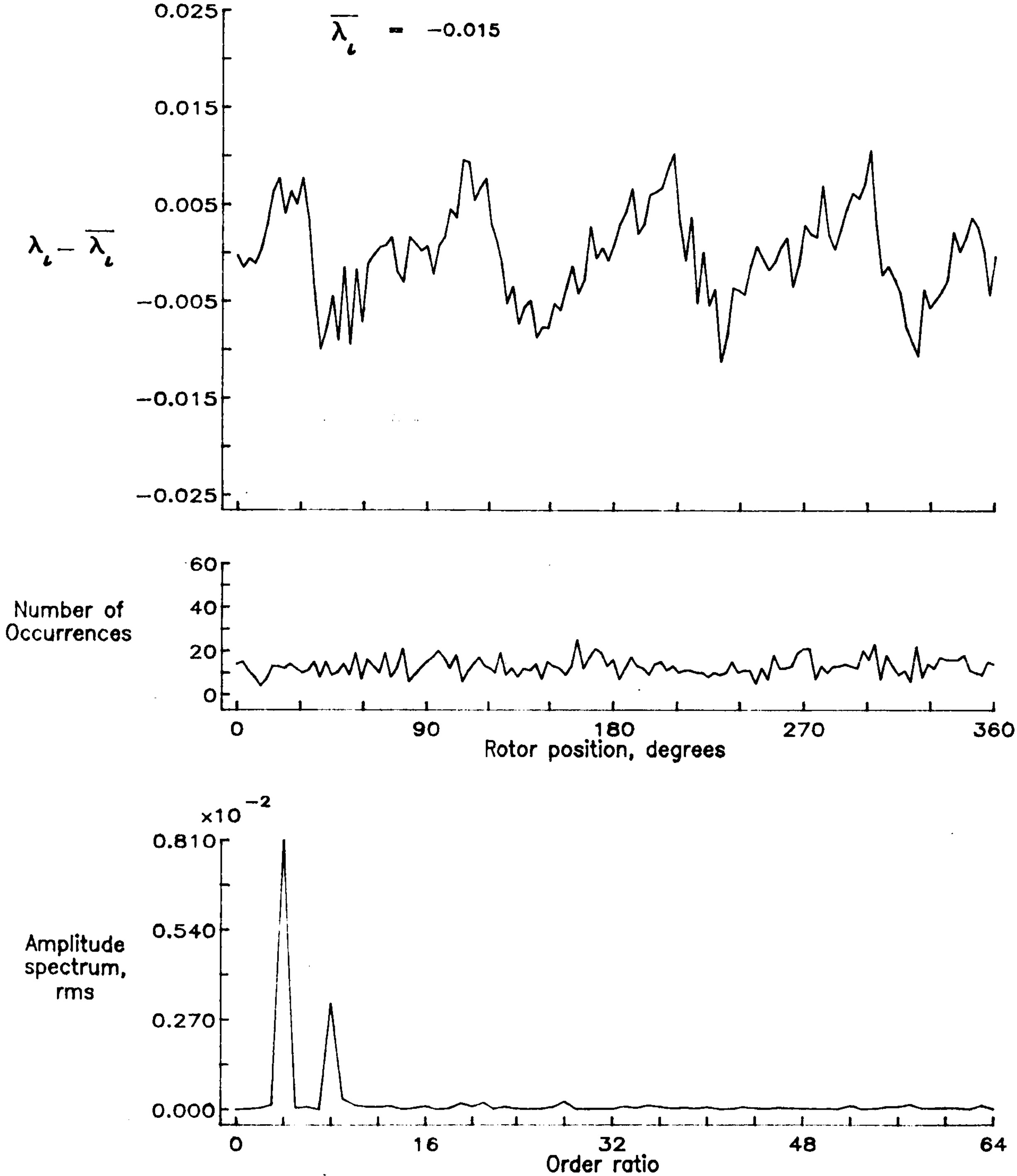


Figure 173.– Induced inflow velocity measured at 300 degrees and r/R of 0.94.



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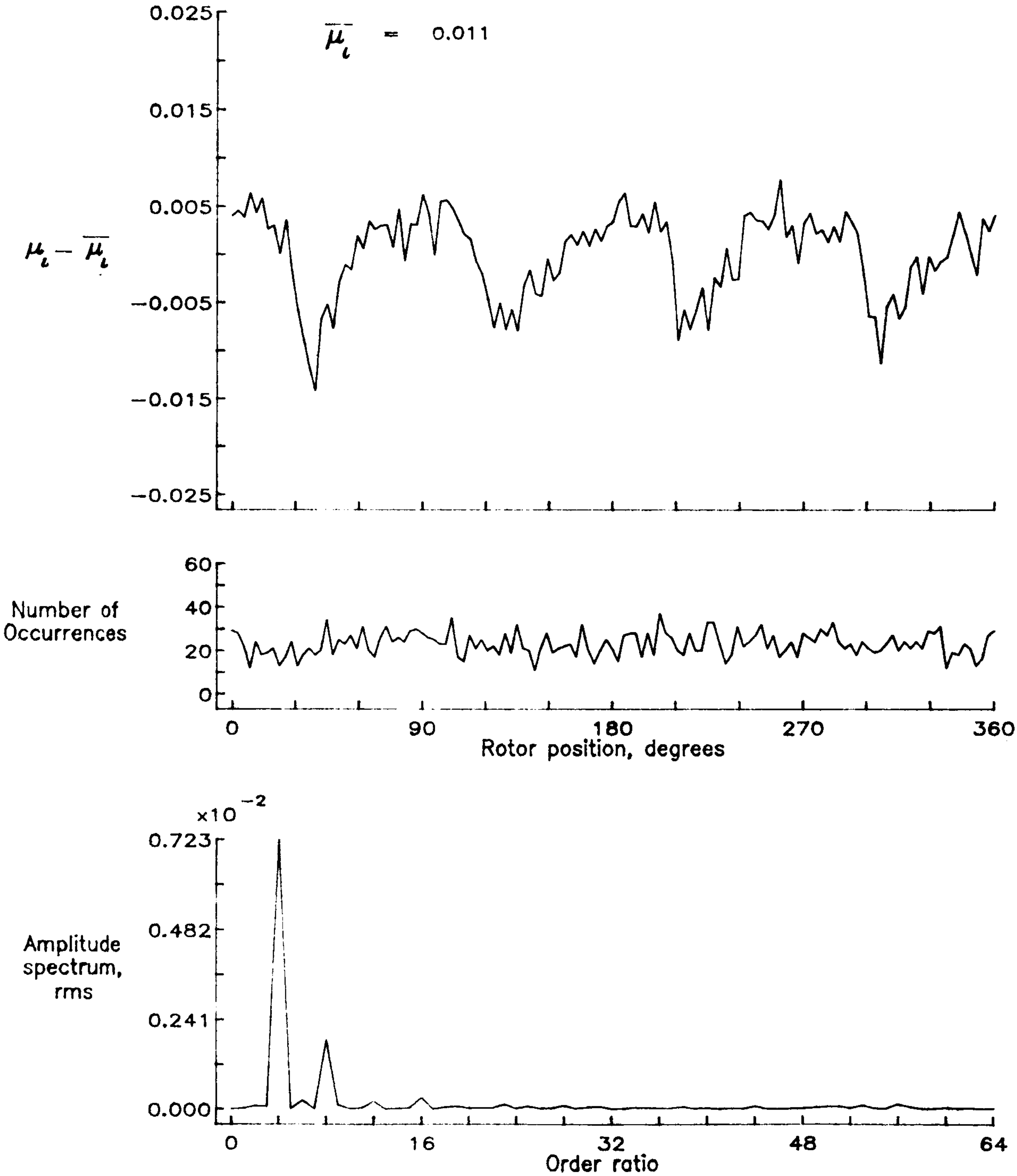
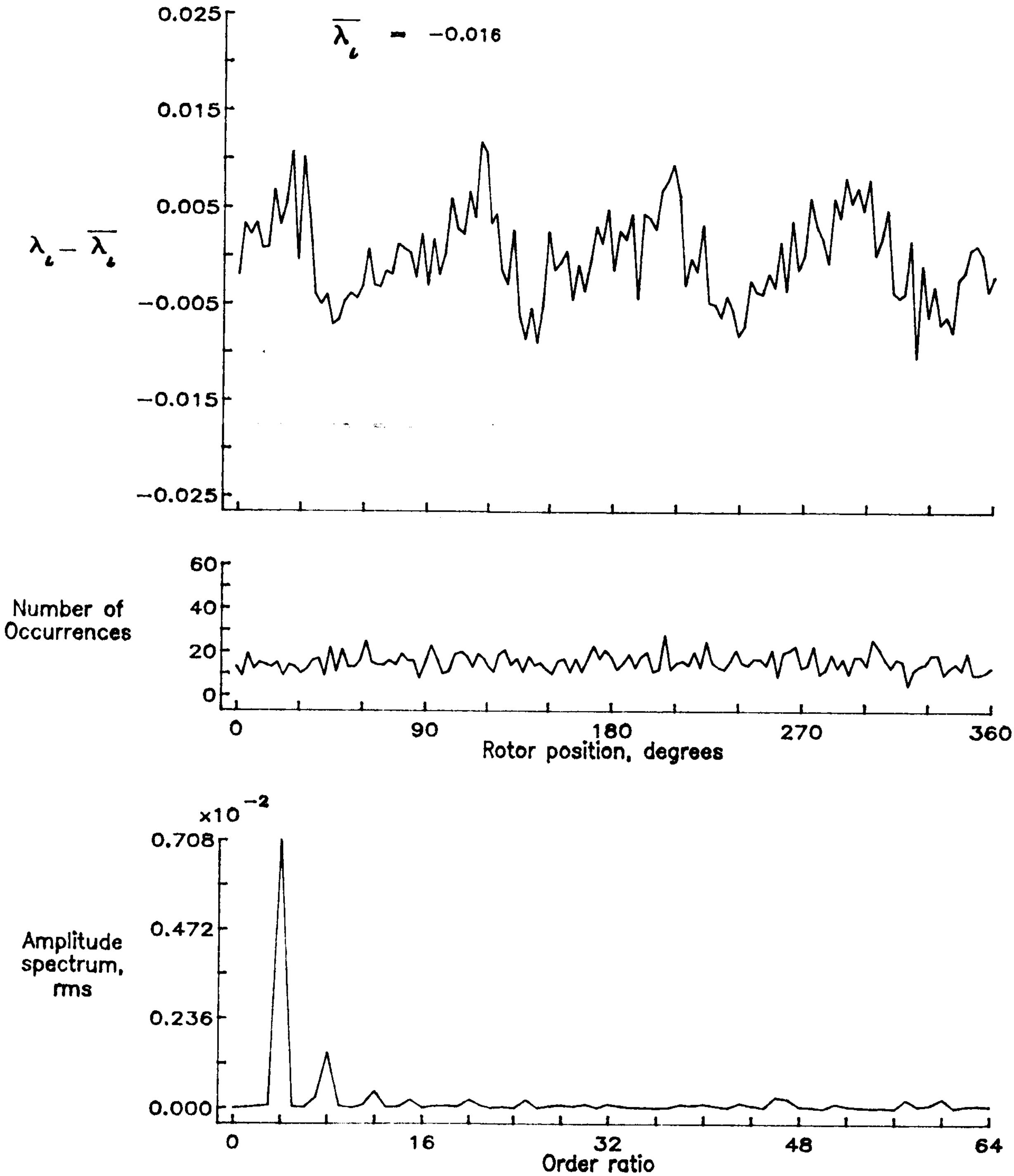


Figure 174.– Induced inflow velocity measured at 300 degrees and r/R of 0.98.



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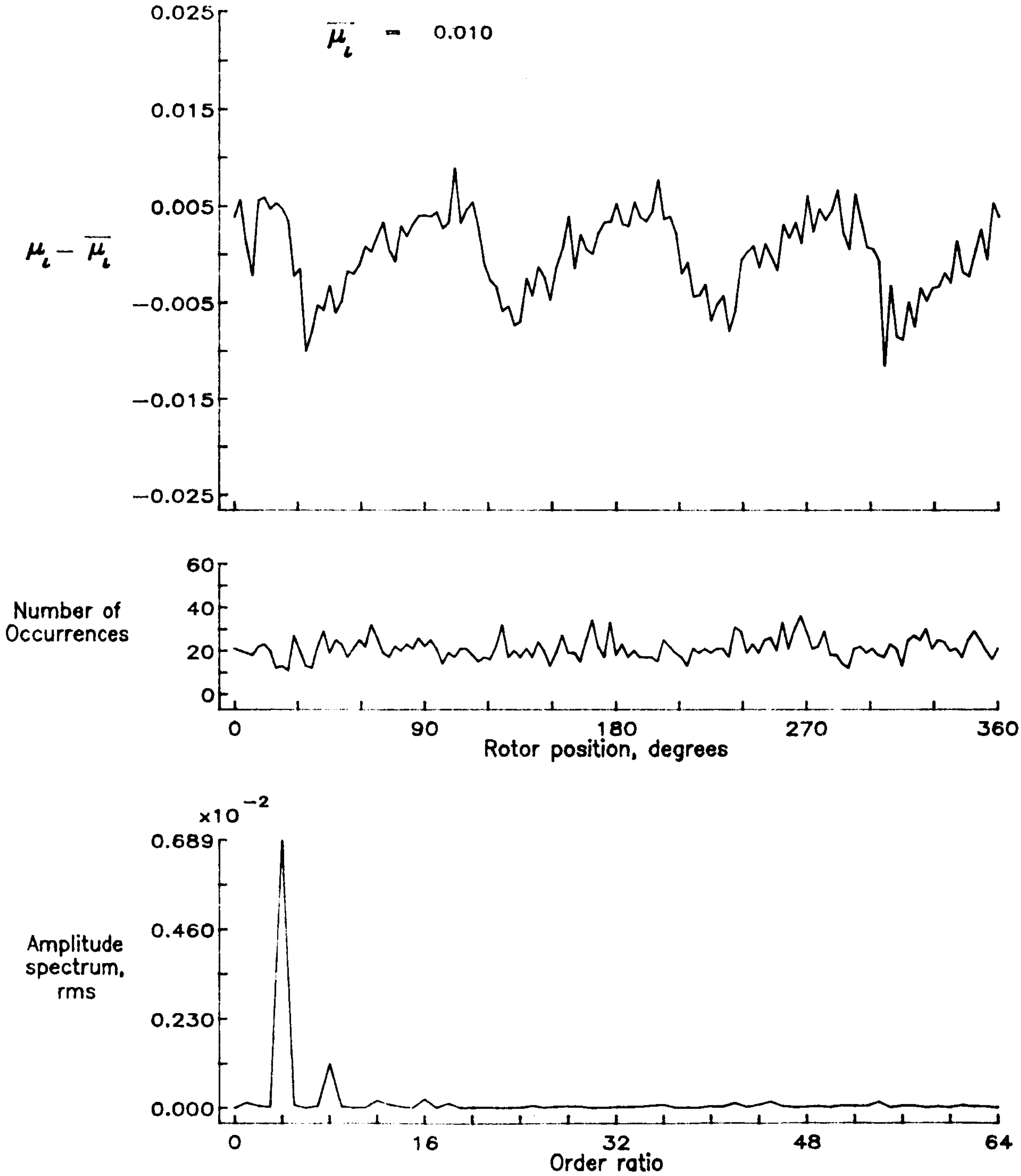


Figure 175.– Induced inflow velocity measured at 300 degrees and r/R of 1.02.

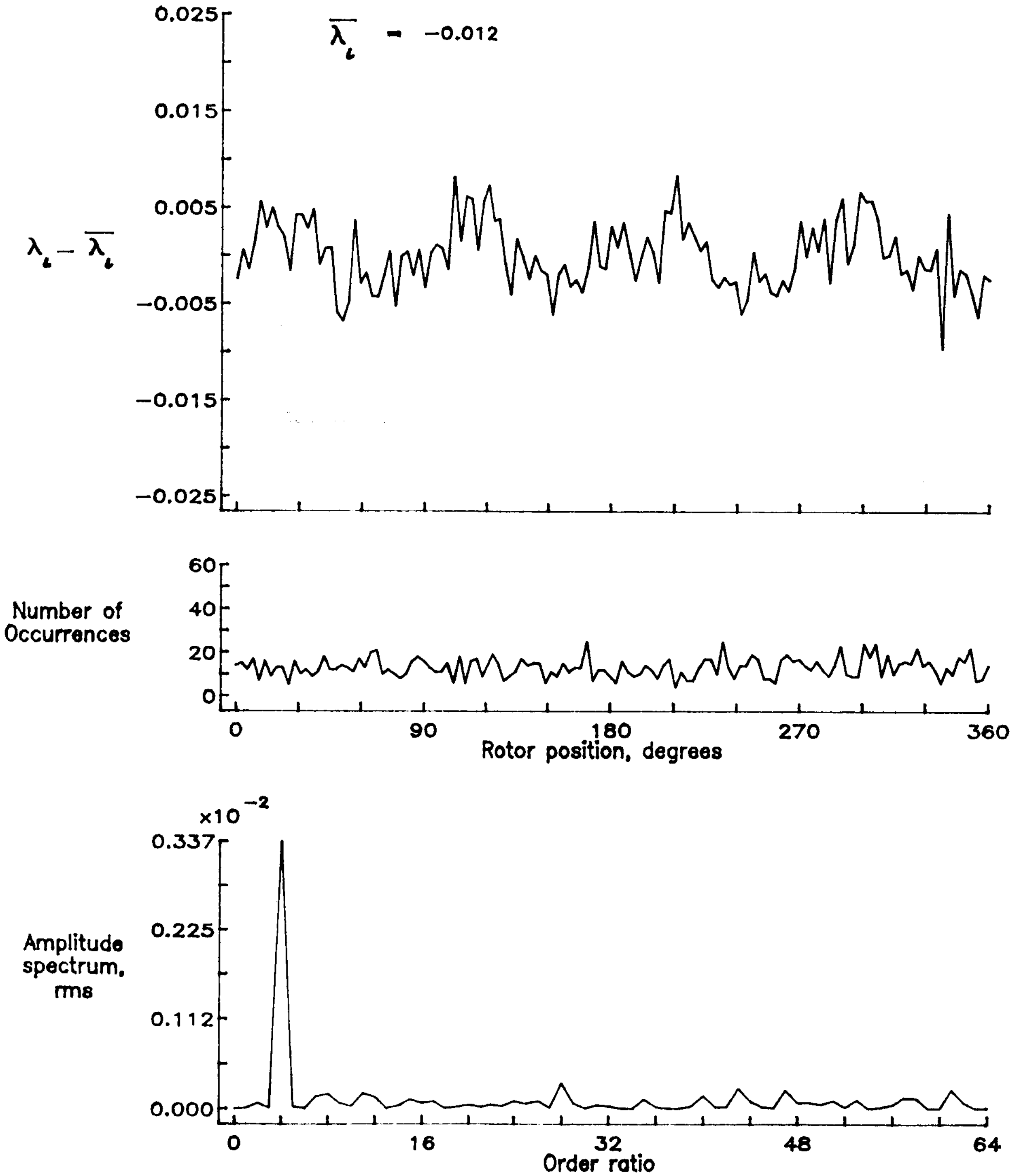


Figure 175.– Concluded.

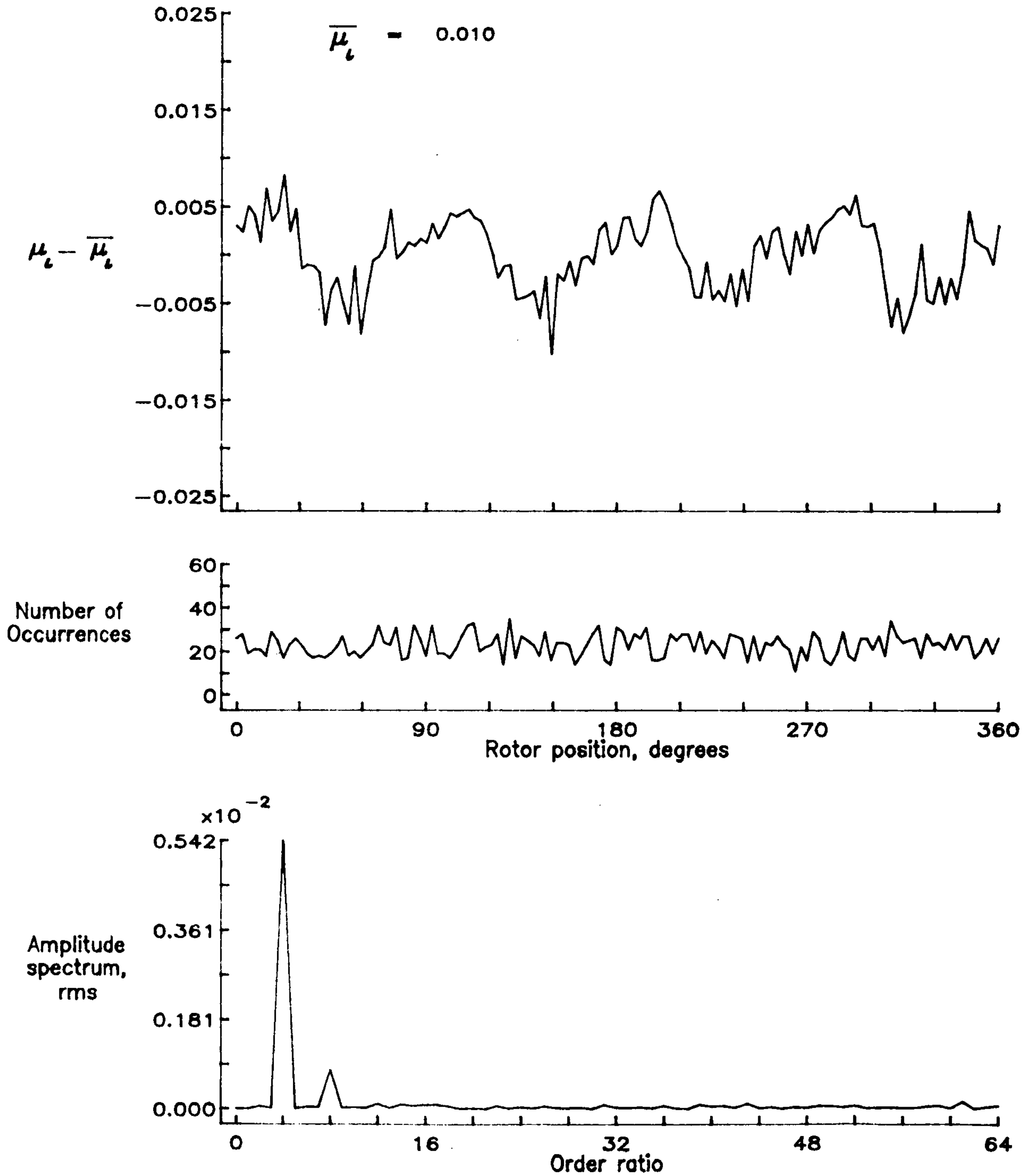


Figure 176.– Induced inflow velocity measured at 300 degrees and r/R of 1.04.

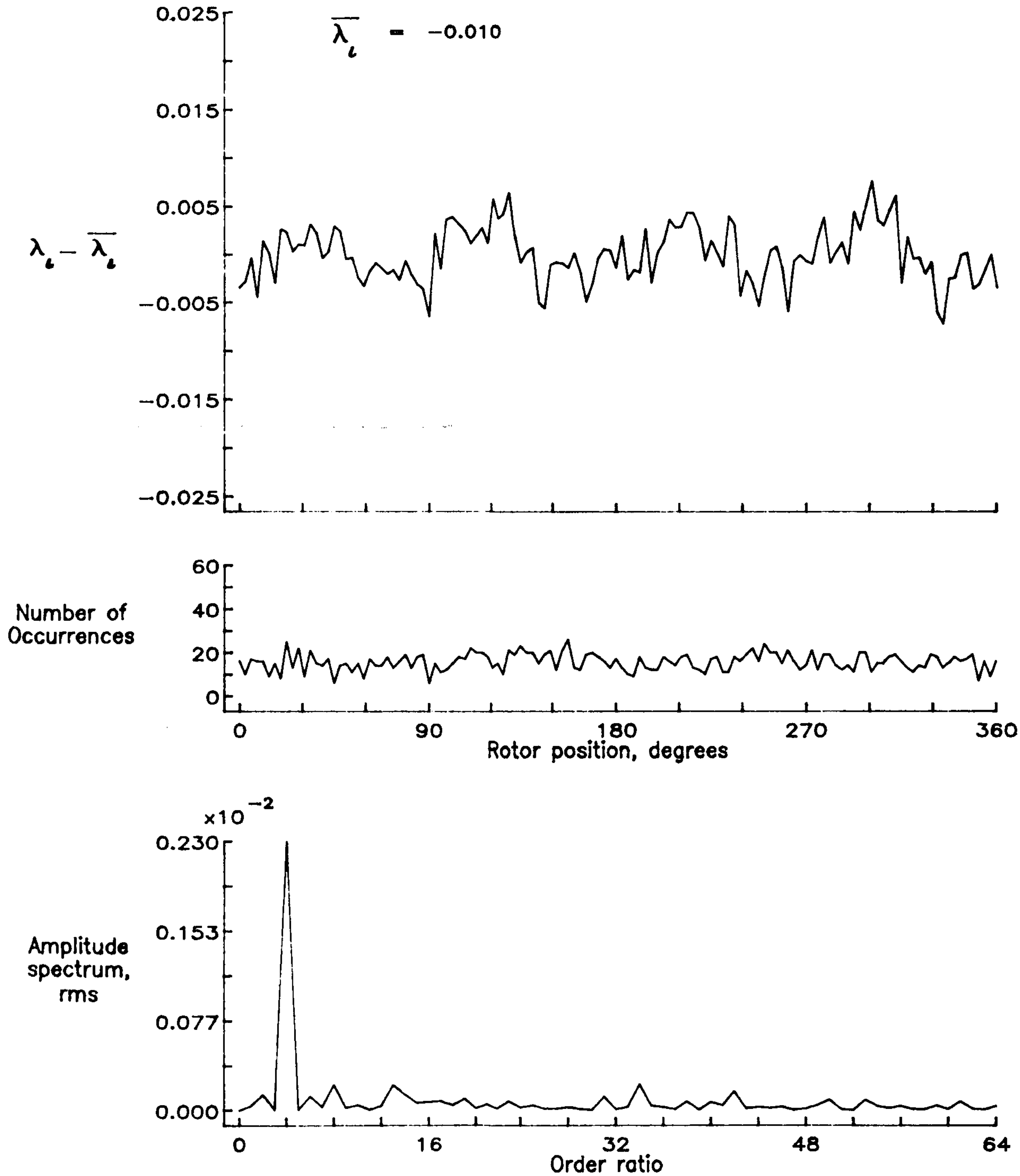


Figure 176.– Concluded.

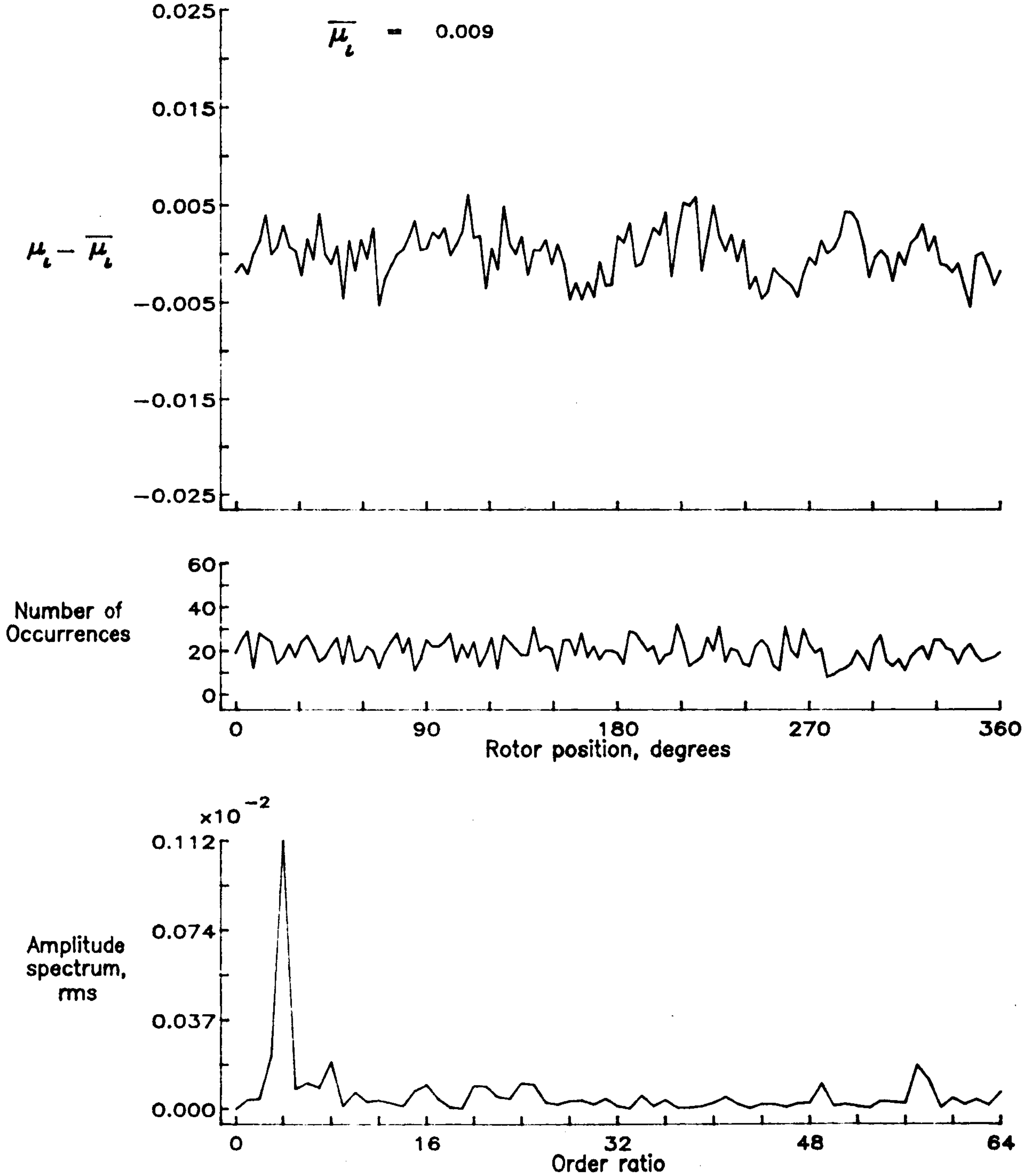


Figure 177.– Induced inflow velocity measured at 300 degrees and r/R of 1.10.

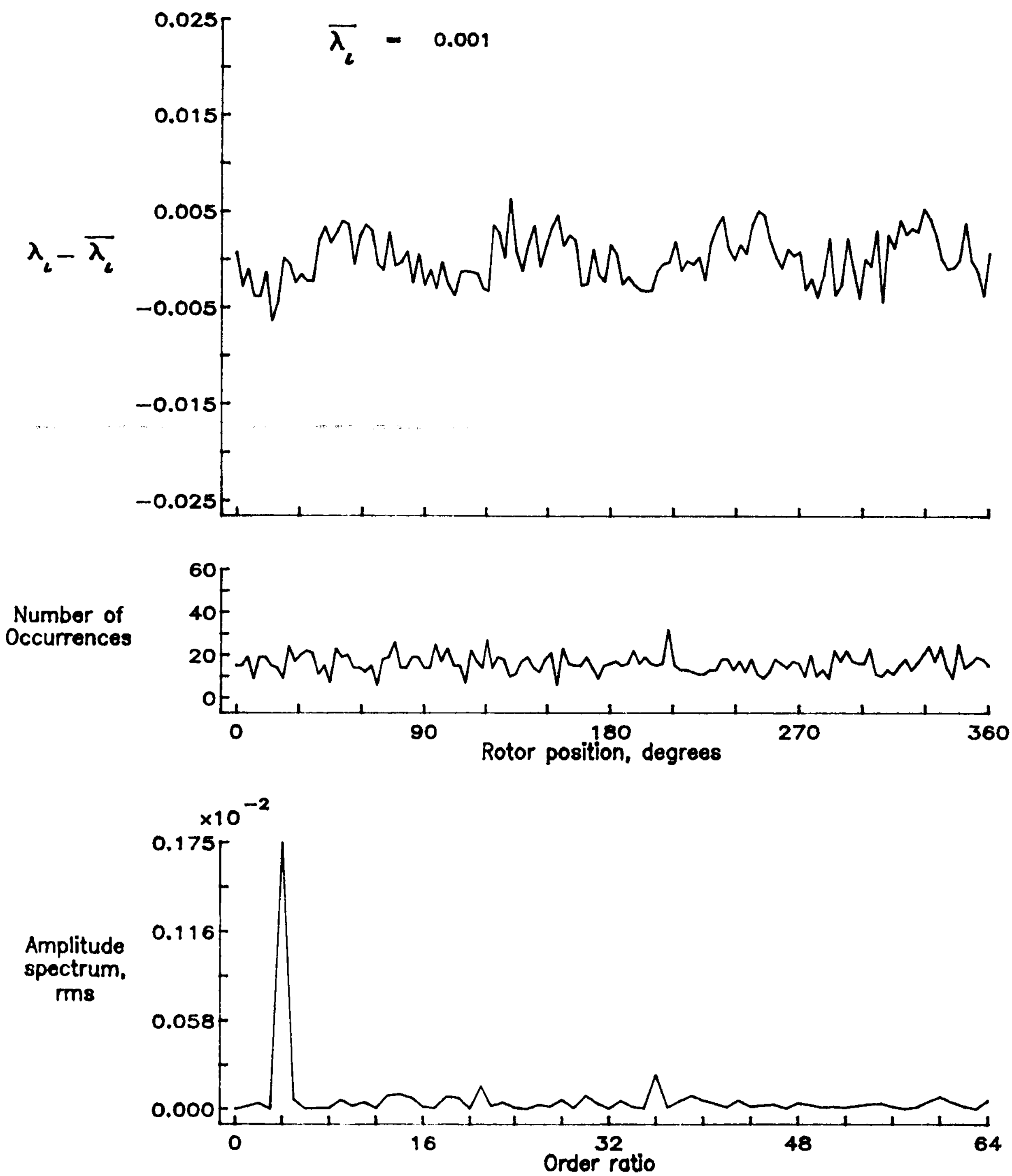


Figure 177.– Concluded.

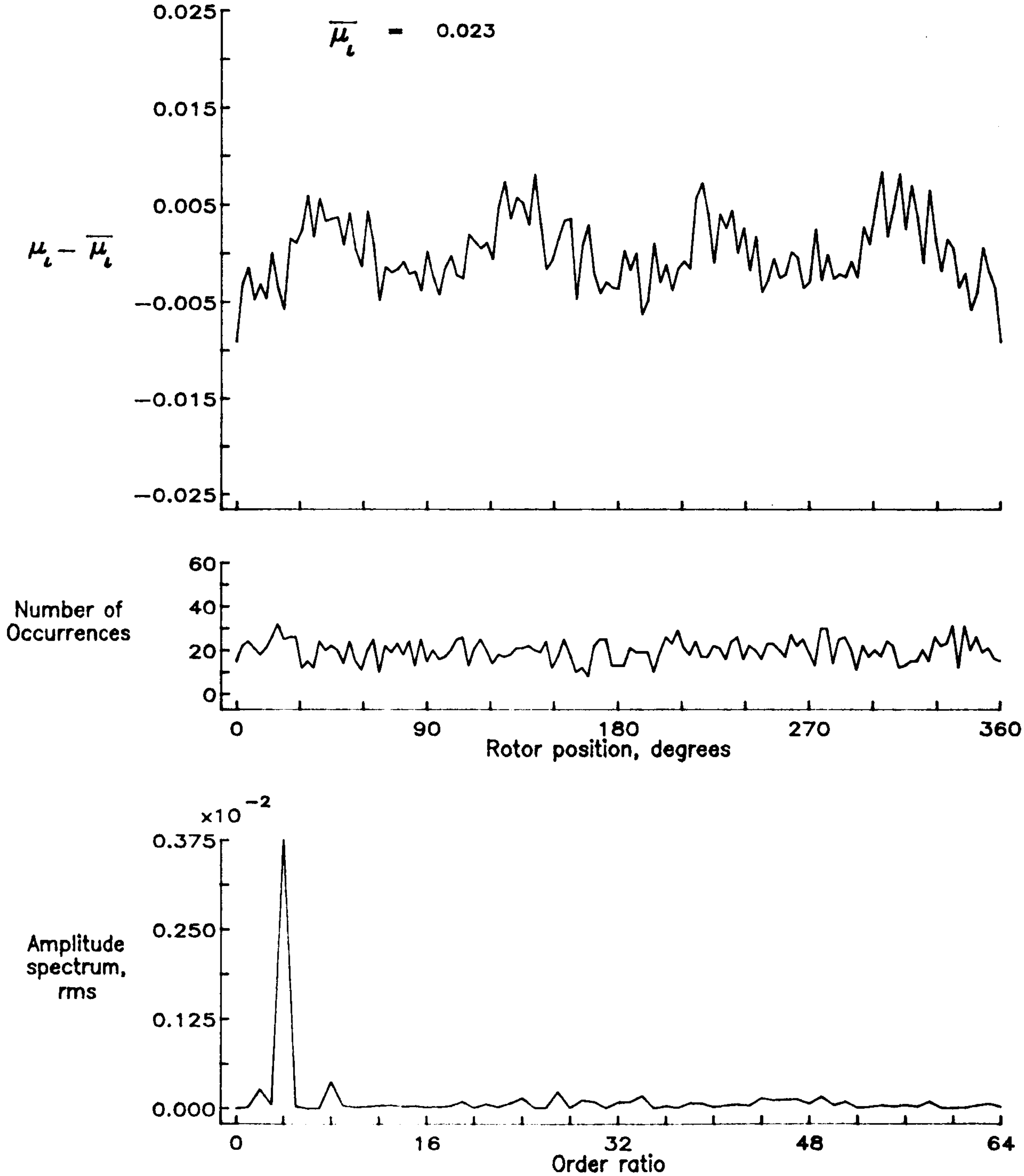


Figure 178.– Induced inflow velocity measured at 330 degrees and r/R of 0.20.

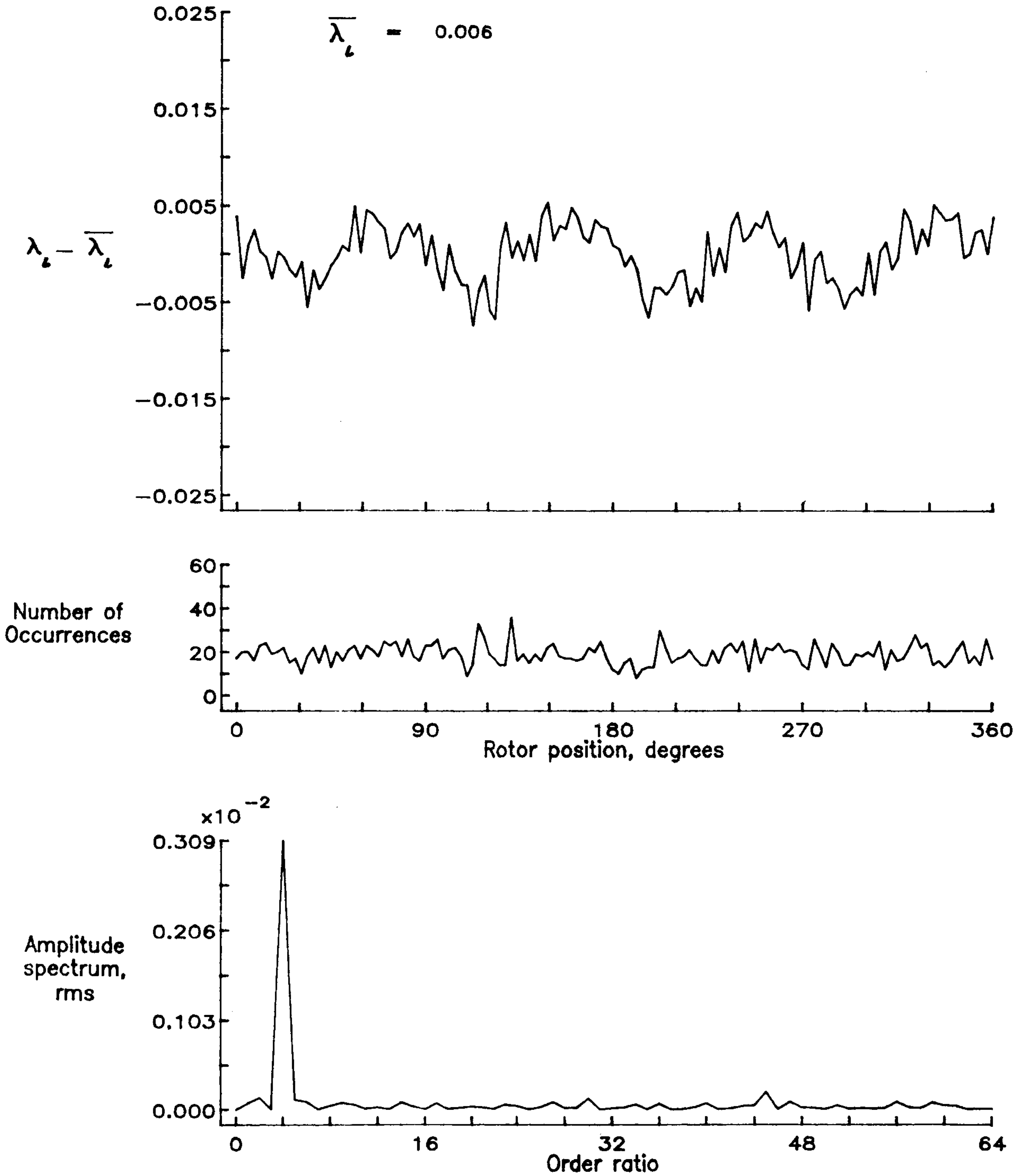


Figure 178.– Concluded.

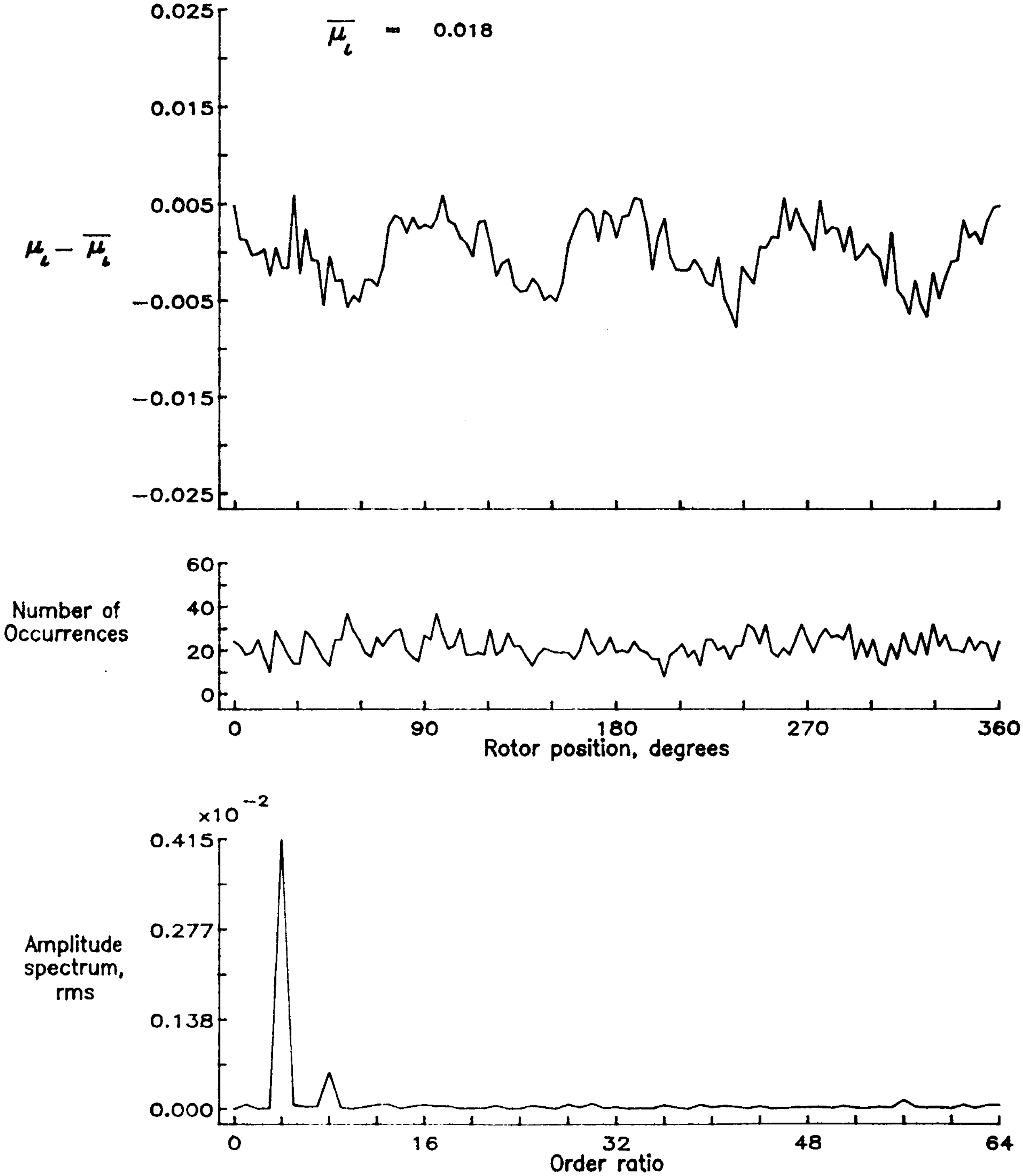
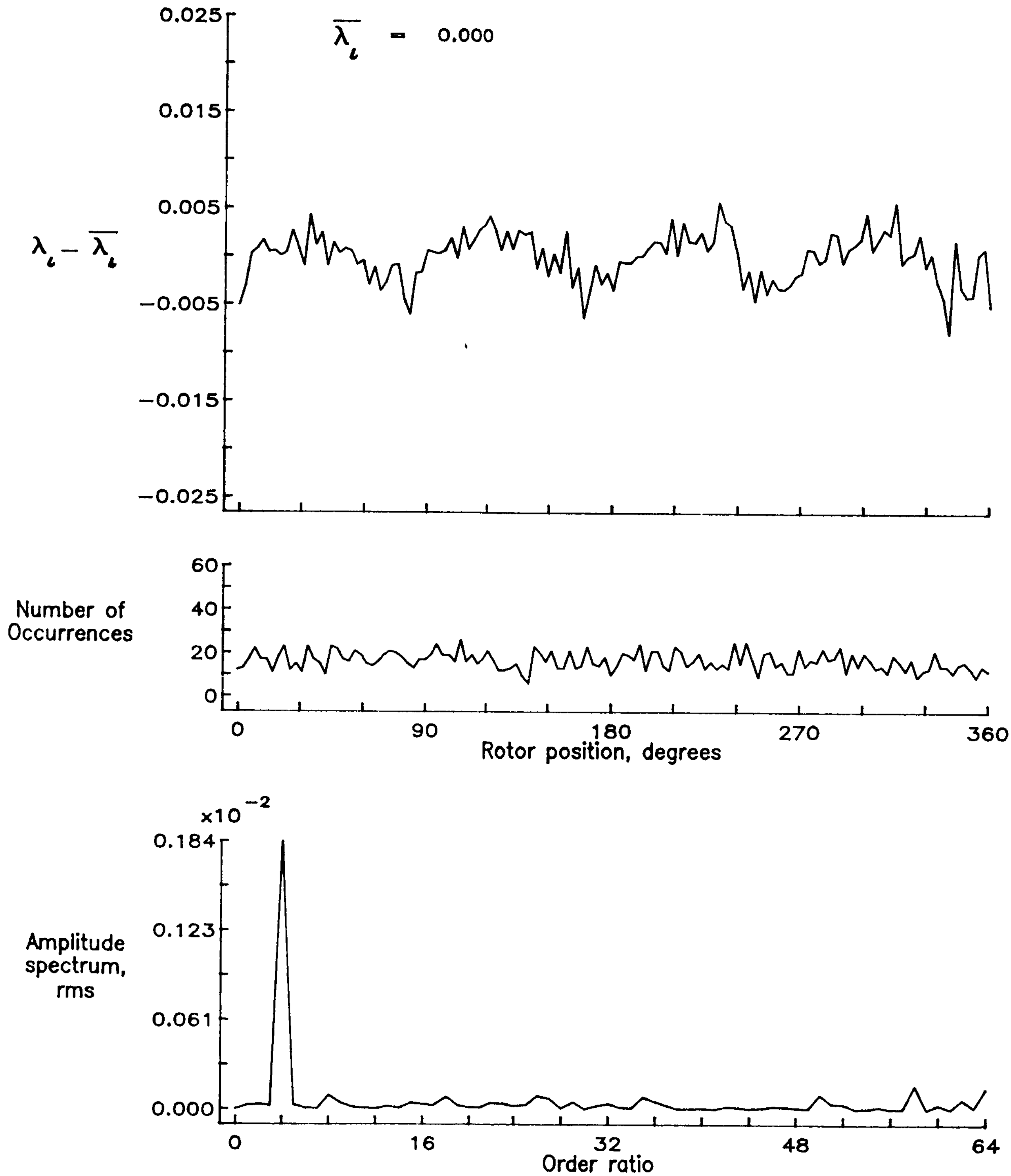


Figure 179.— Induced inflow velocity measured at 330 degrees and r/R of 0.40.



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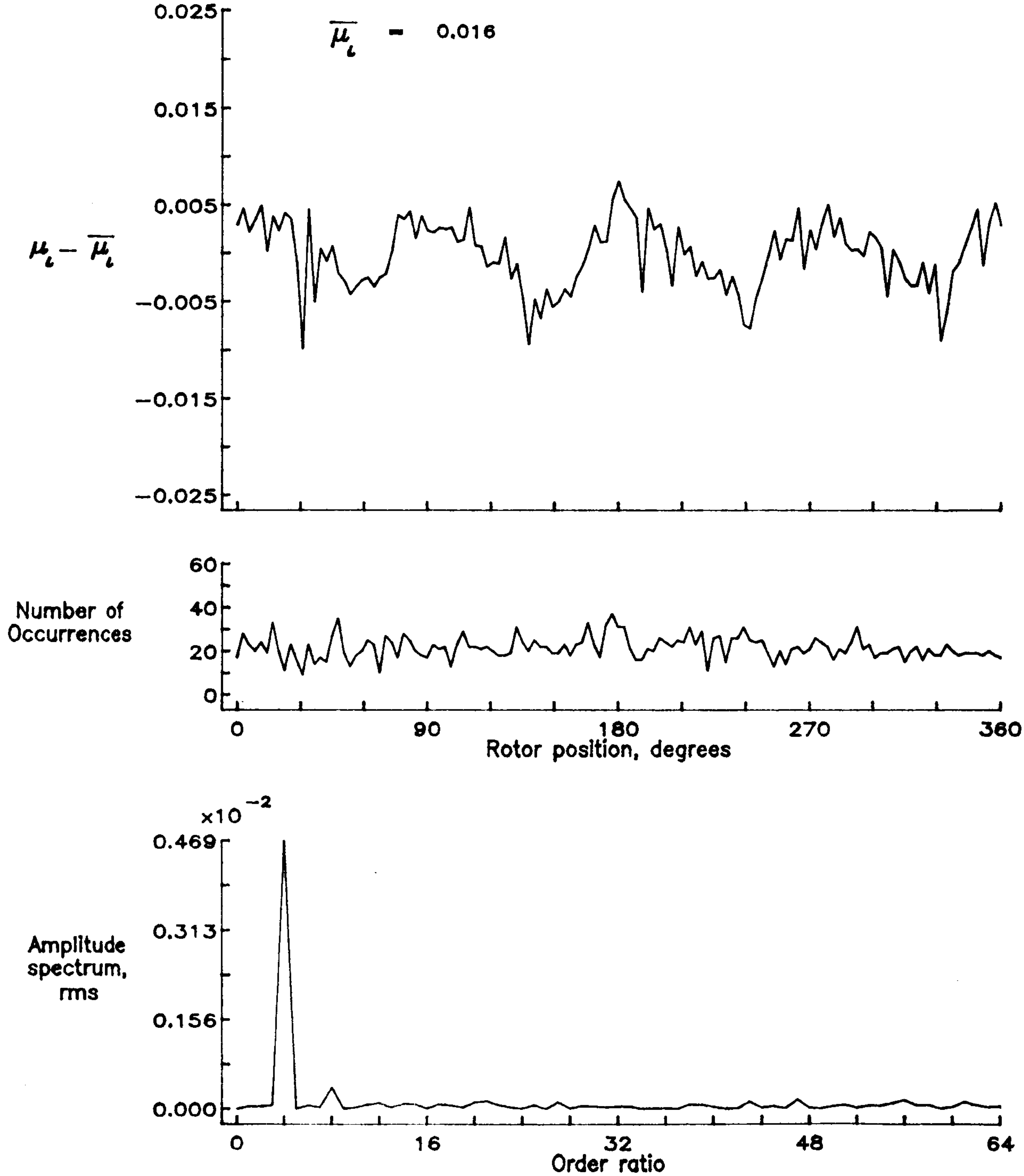

Figure 180.– Induced inflow velocity measured at 330 degrees and r/R of 0.50.

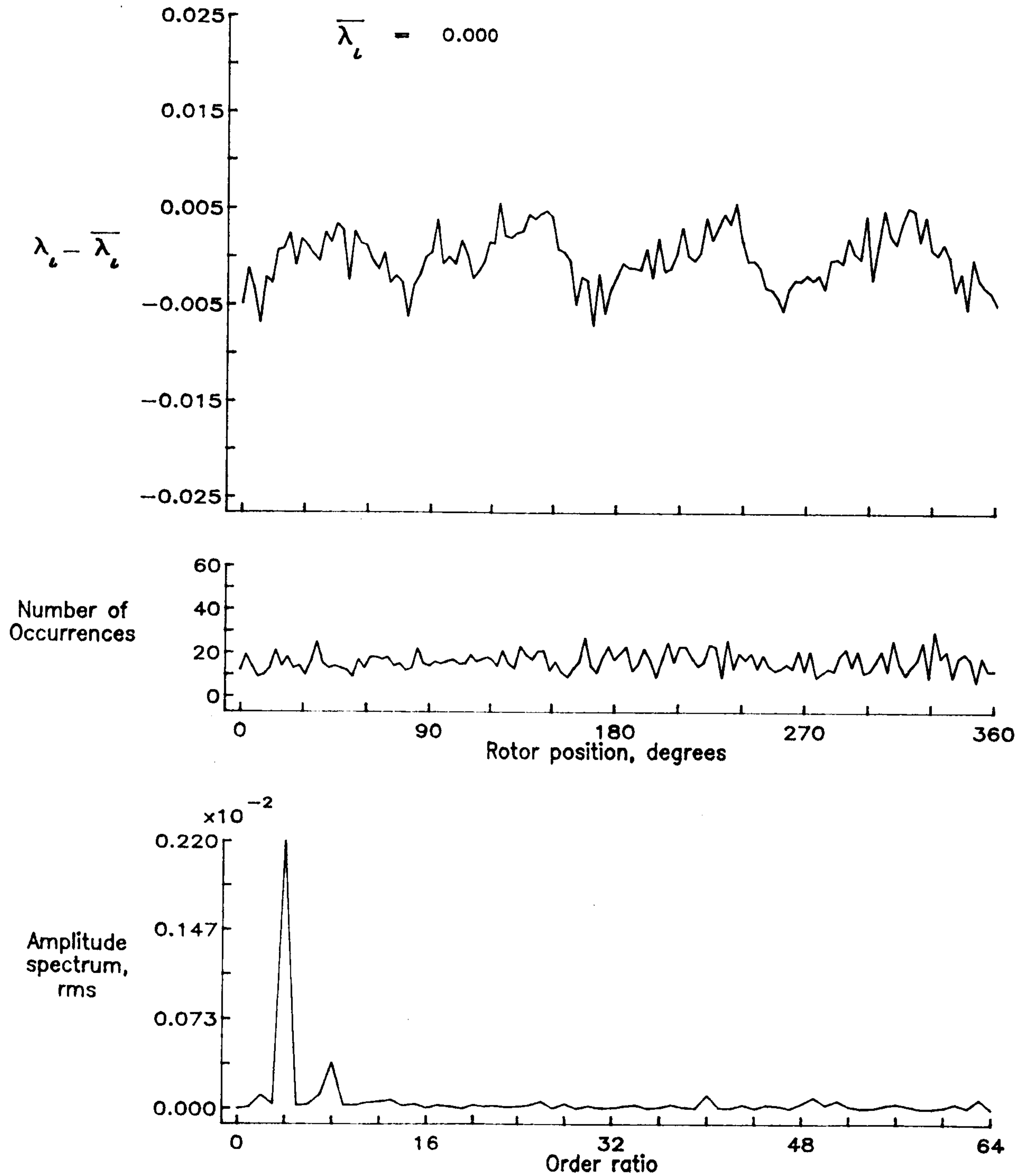

Figure 180.– Concluded.

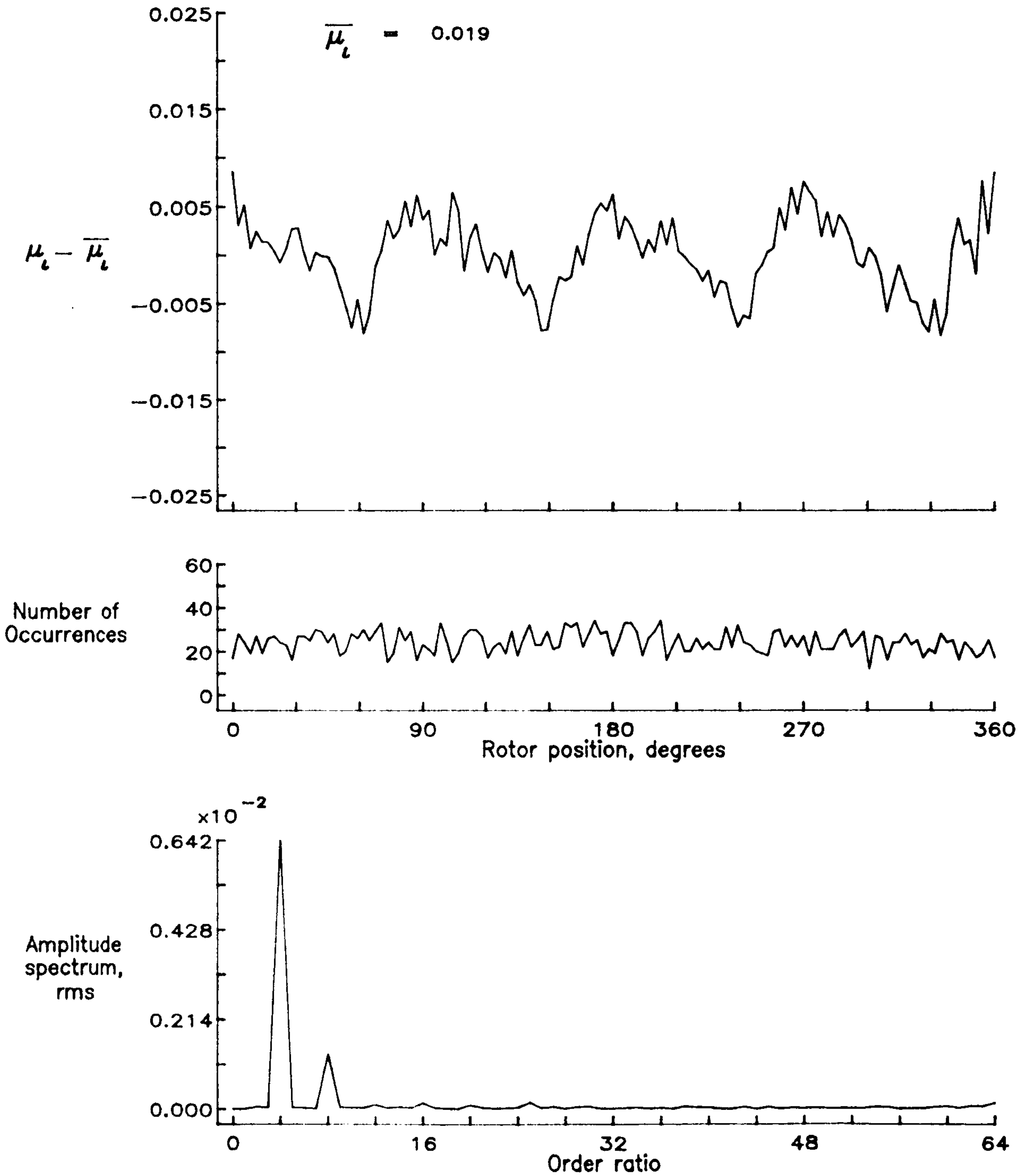

Figure 181.– Induced inflow velocity measured at 330 degrees and r/R of 0.60.

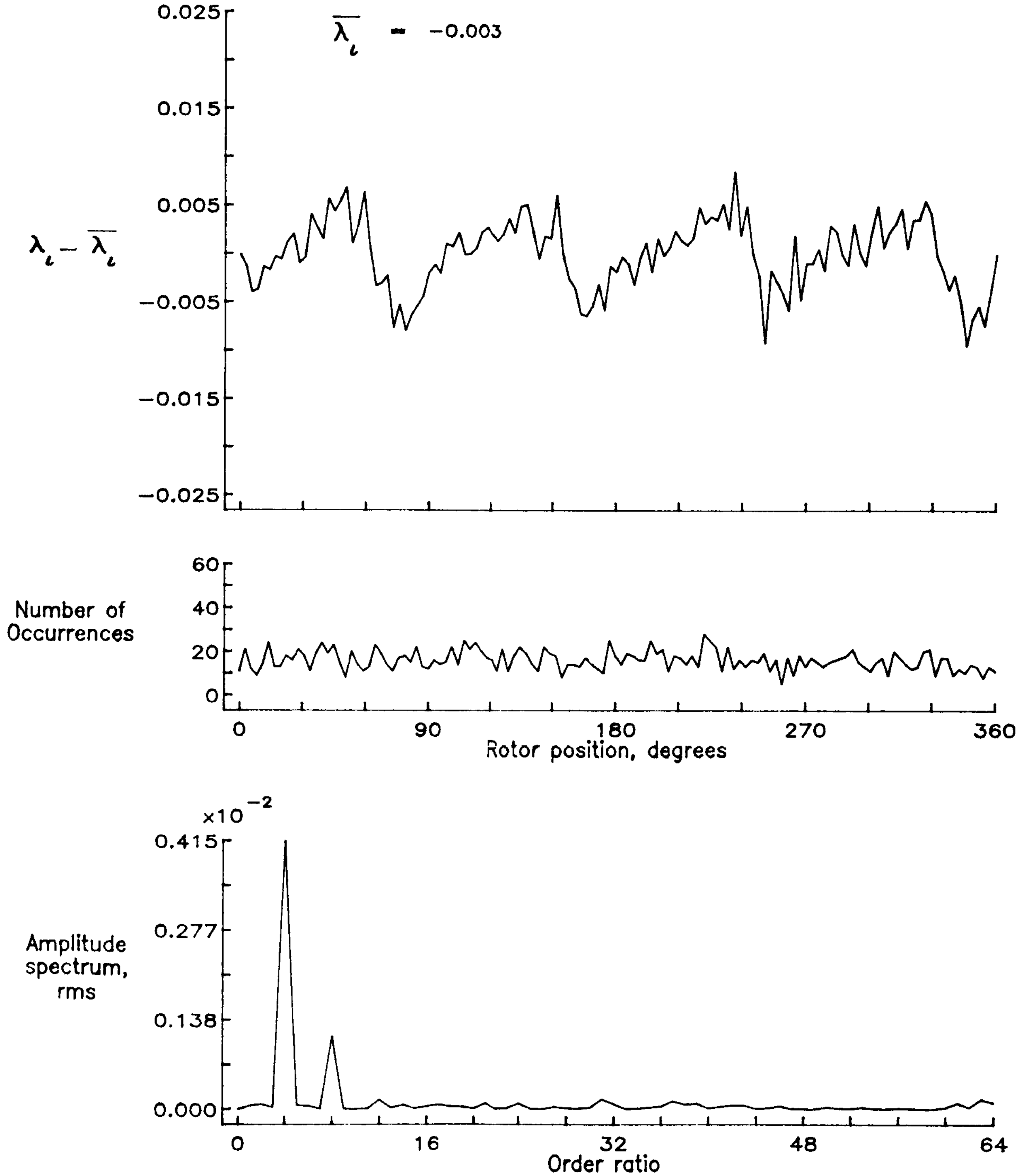

Figure 181.– Concluded.

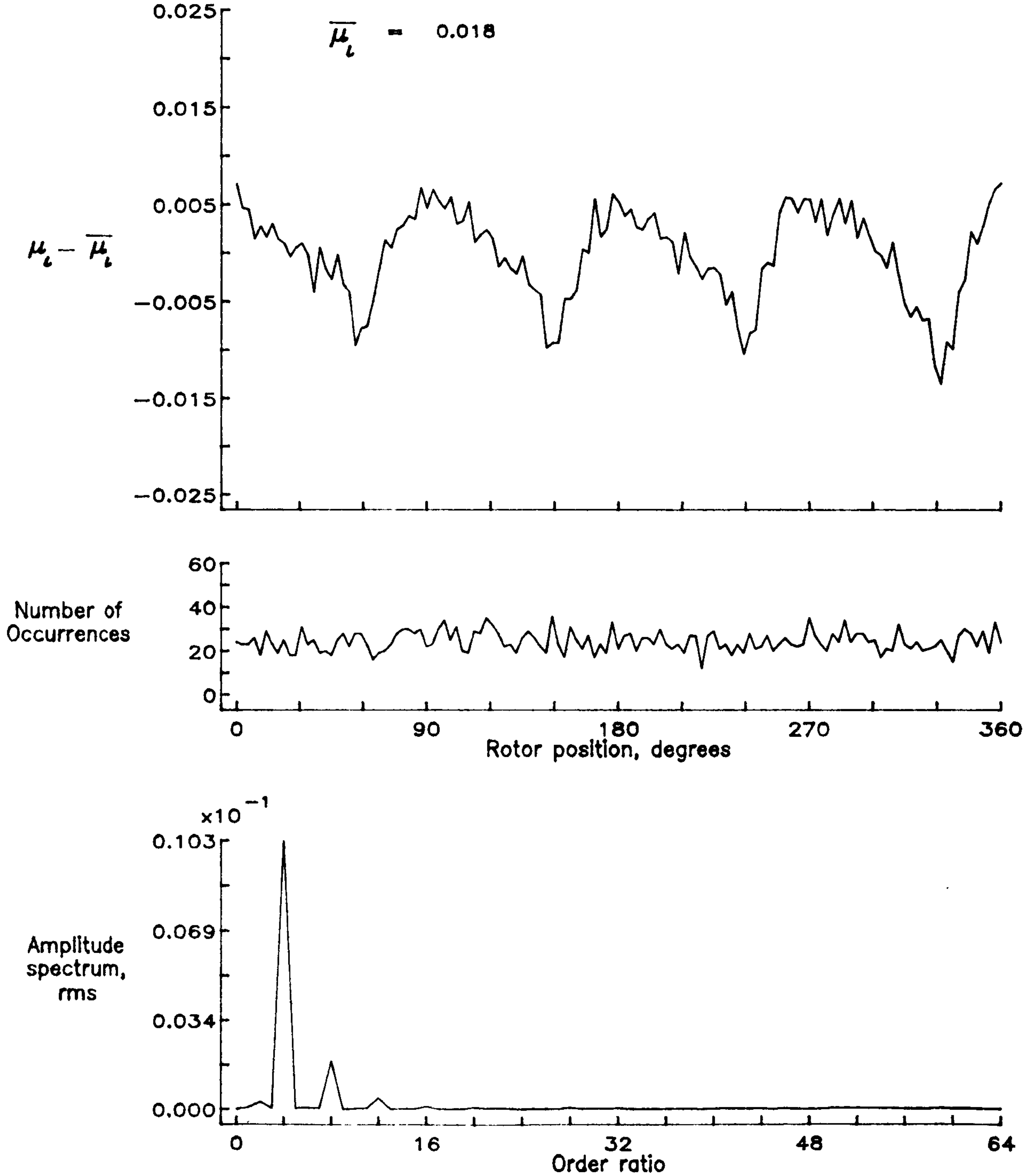

Figure 182.– Induced inflow velocity measured at 330 degrees and r/R of 0.70.

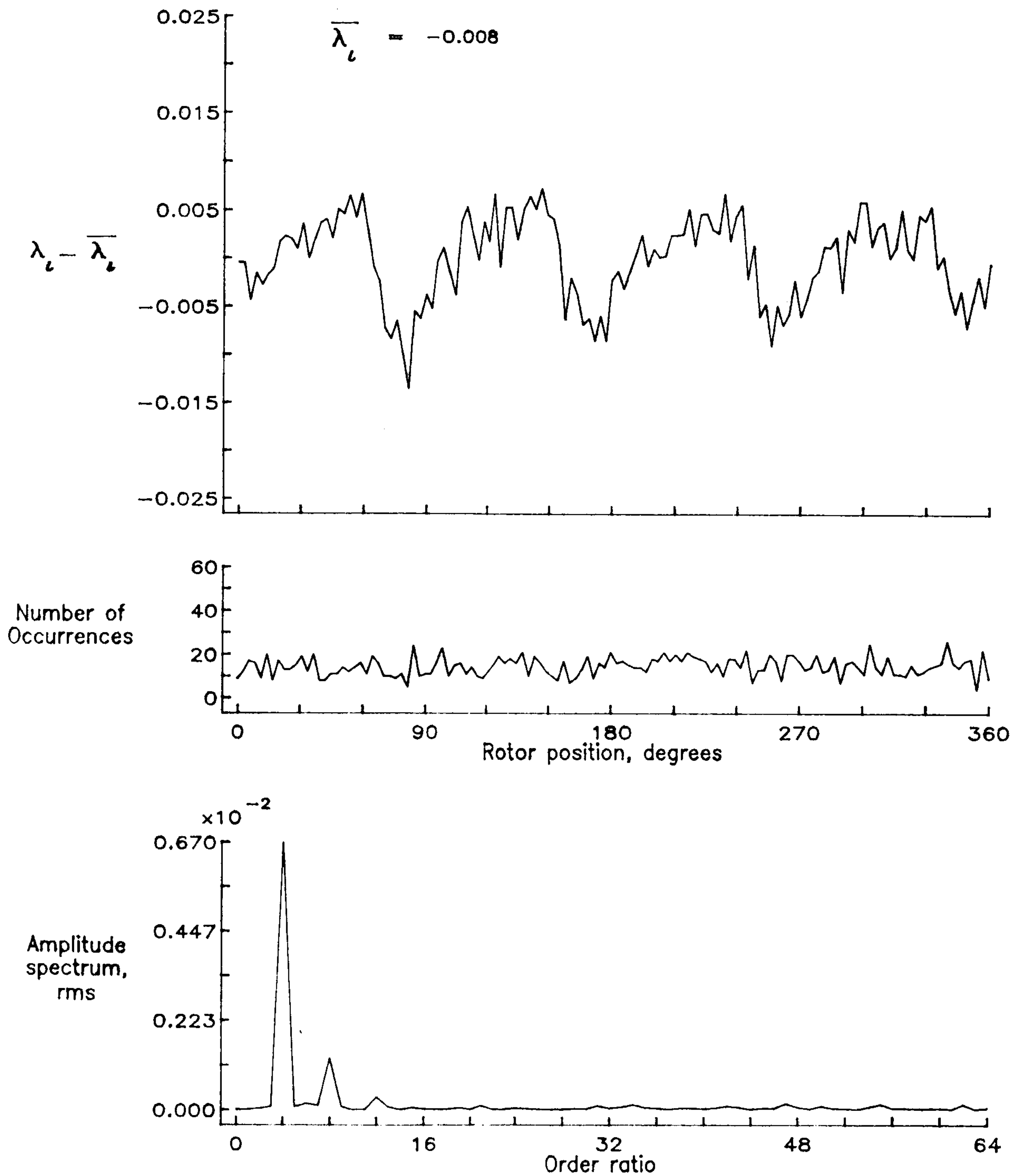

Figure 182.– Concluded.

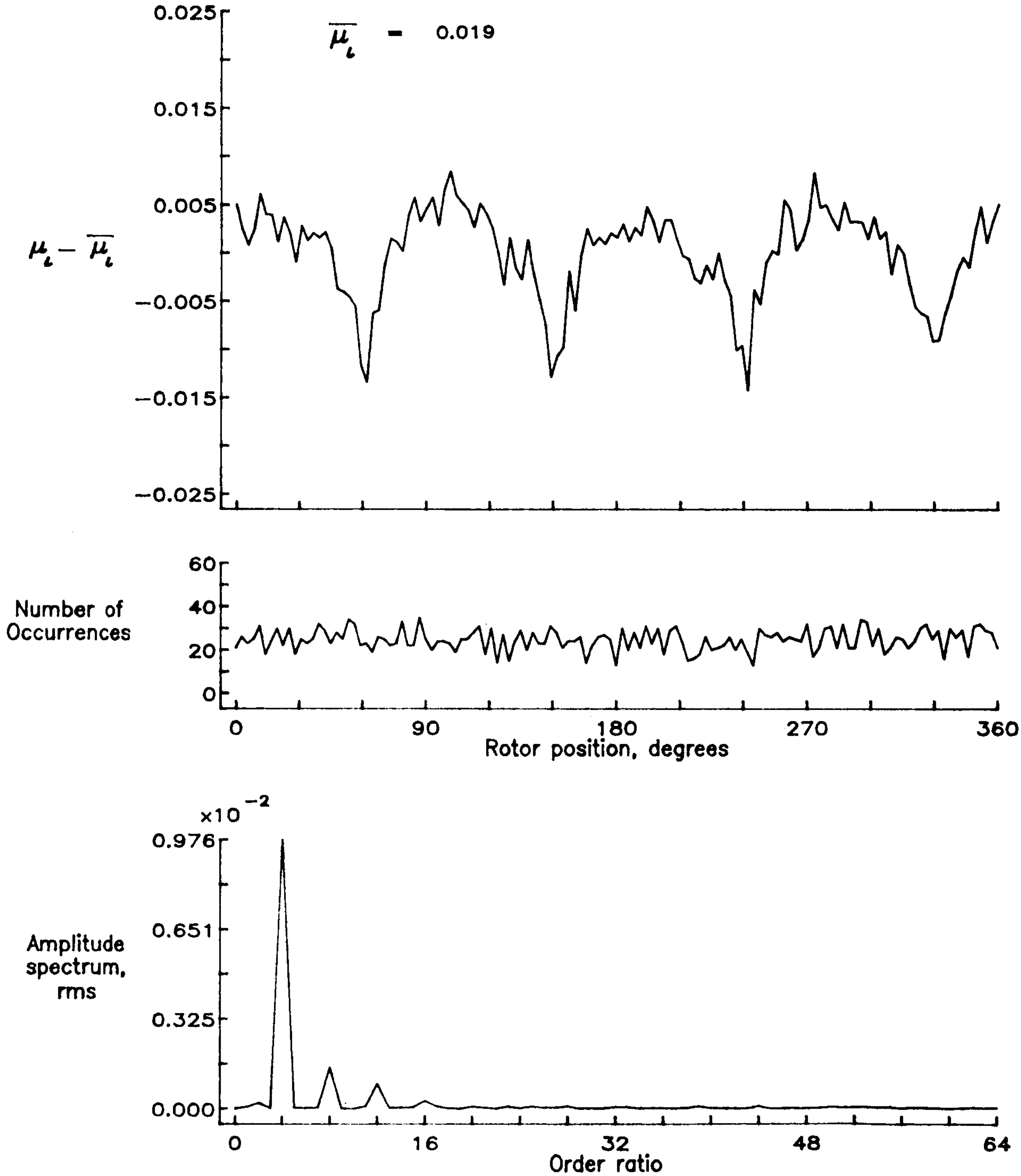

Figure 183.– Induced inflow velocity measured at 330 degrees and r/R of 0.74.

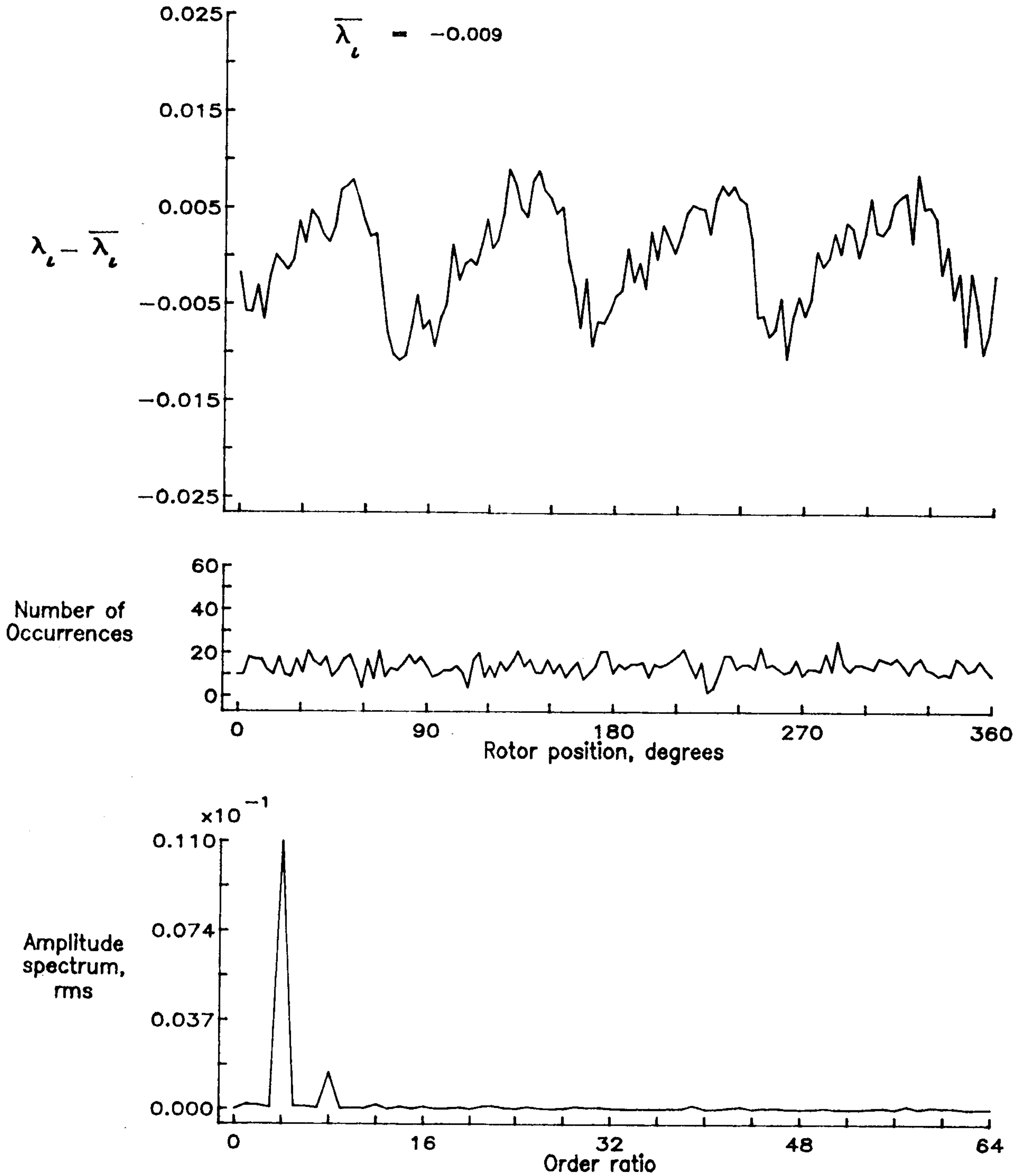

Figure 183.– Concluded.

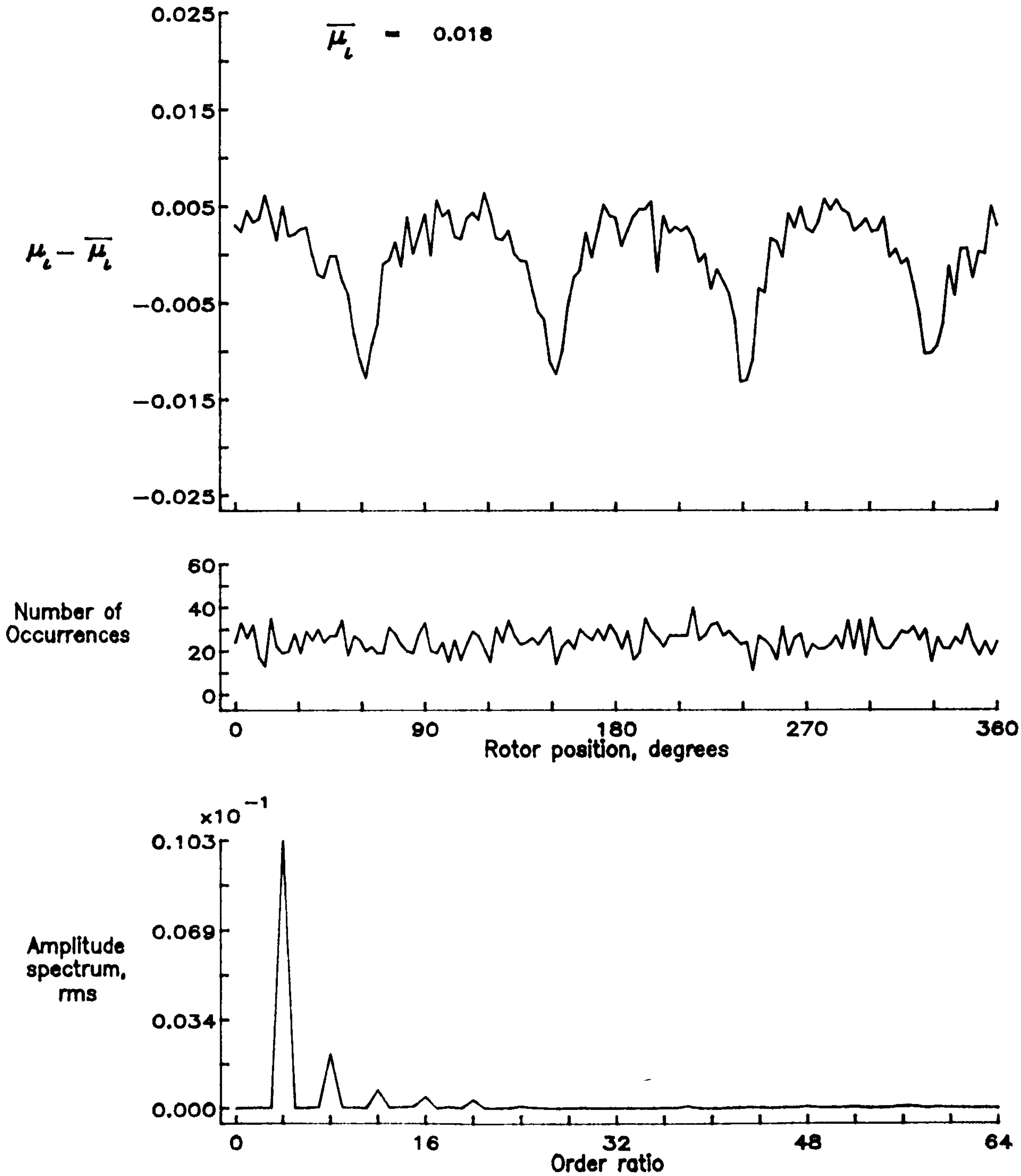

Figure 184.— Induced inflow velocity measured at 330 degrees and r/R of 0.78.

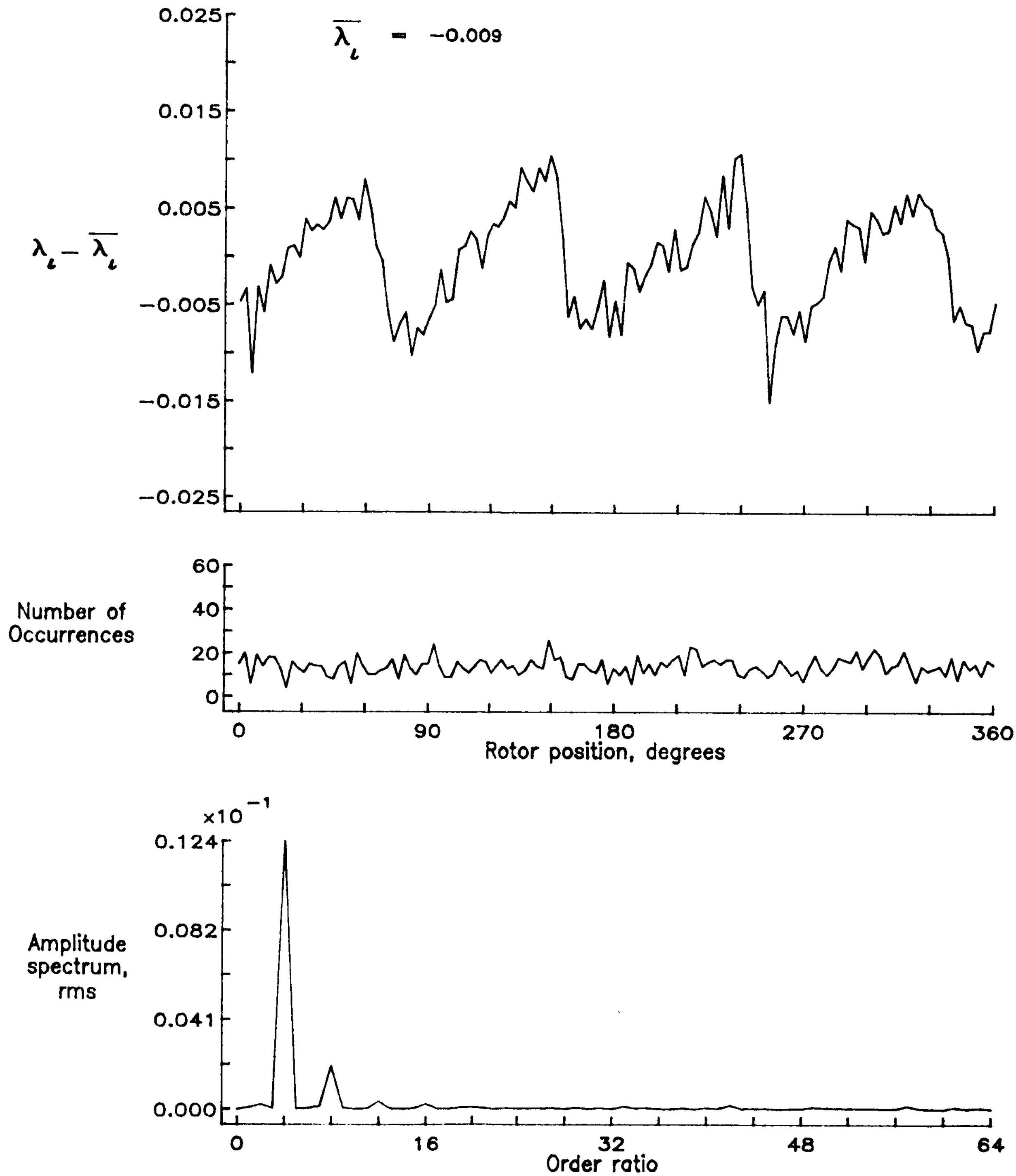

Figure 184.– Concluded.

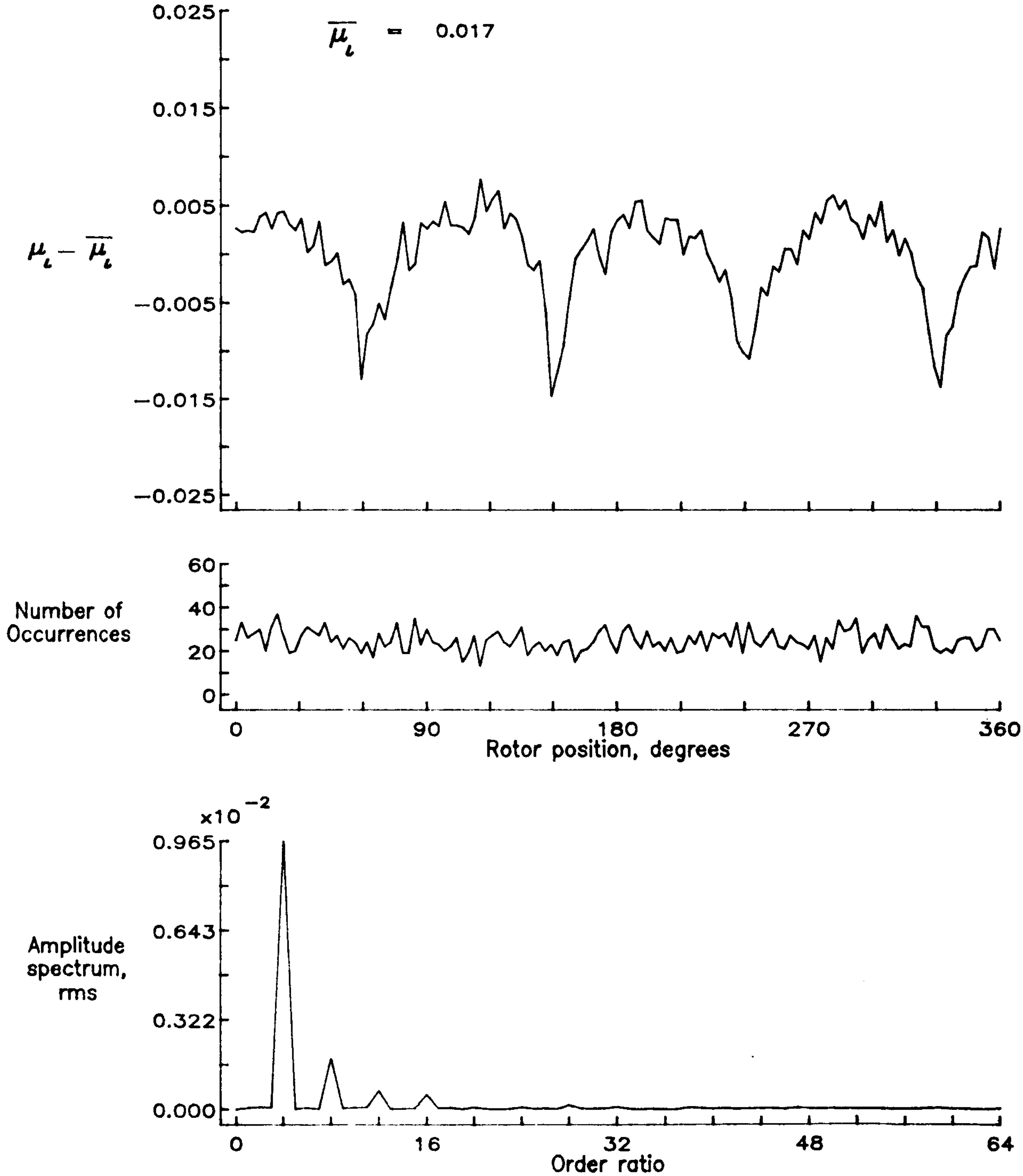

Figure 185.– Induced inflow velocity measured at 330 degrees and r/R of 0.82.

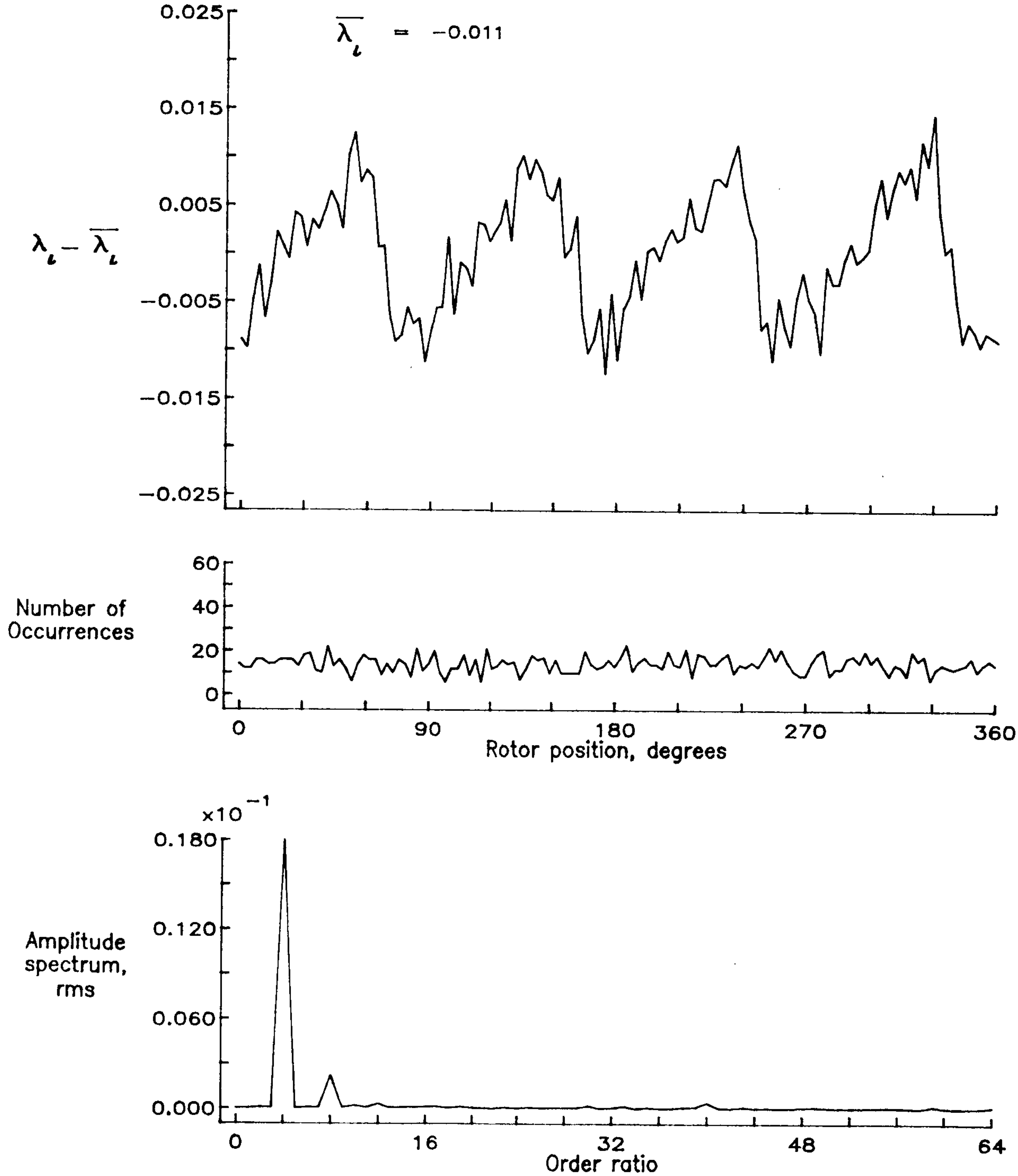

Figure 185.– Concluded.

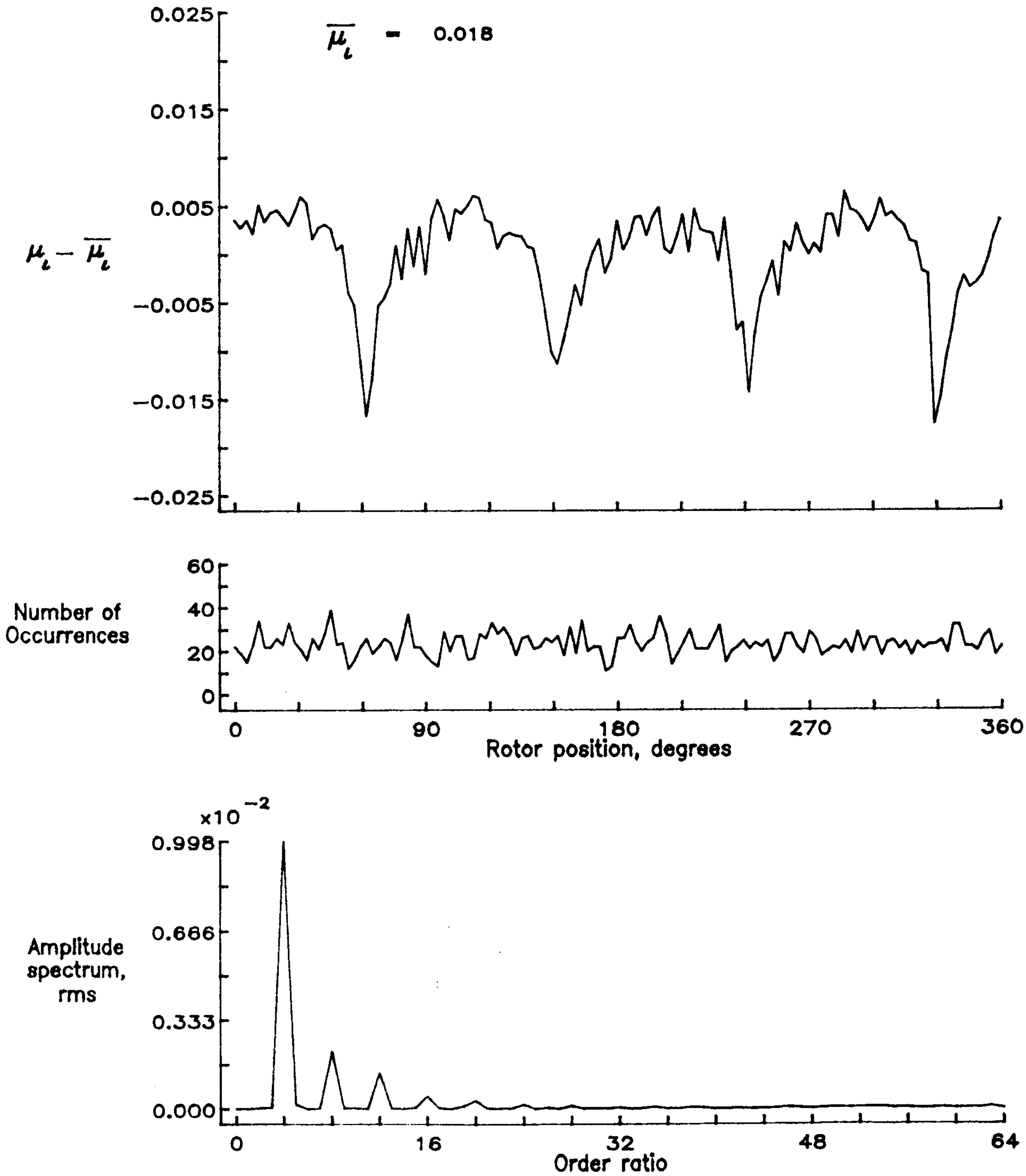

Figure 186.– Induced inflow velocity measured at 330 degrees and r/R of 0.86.

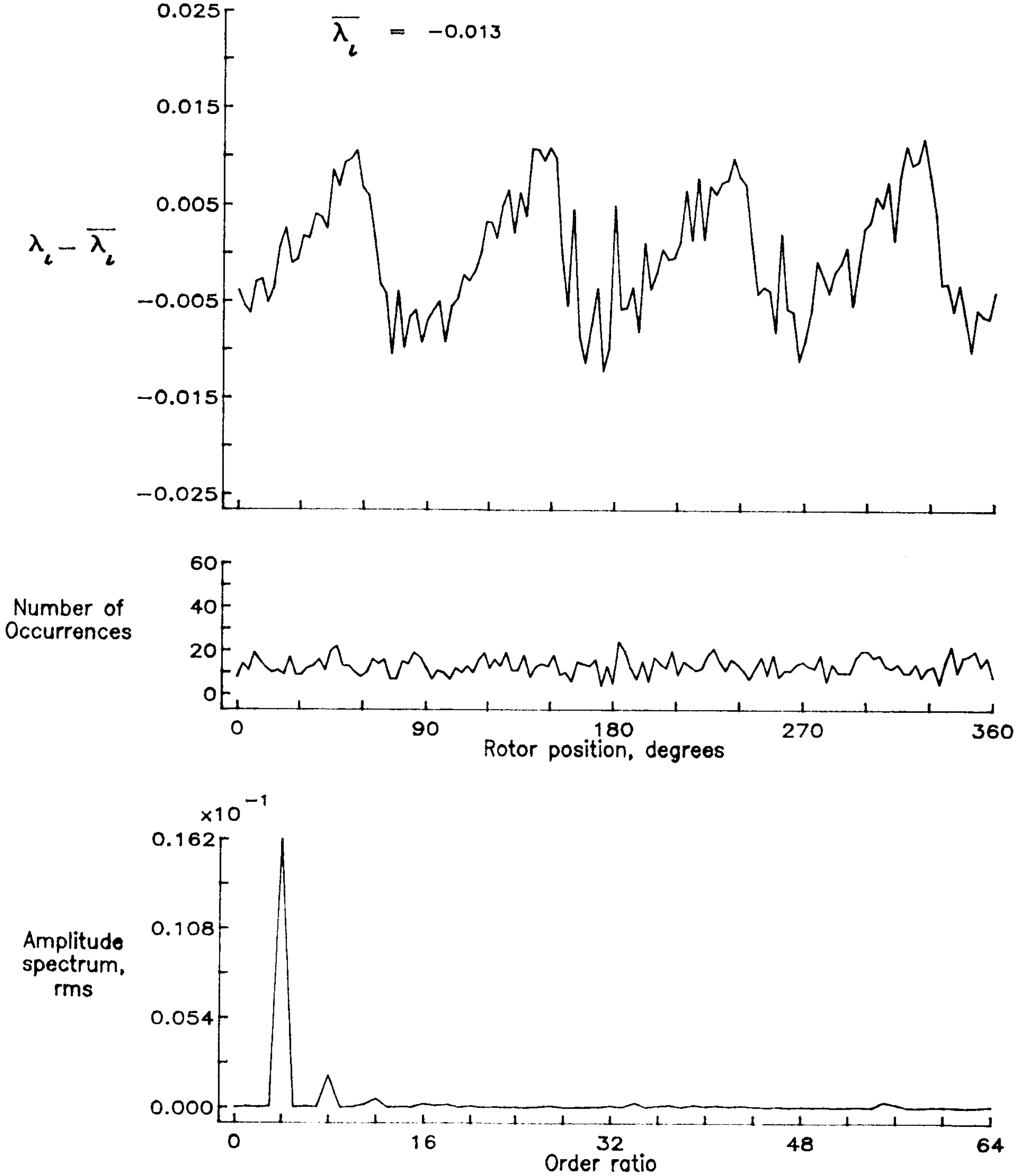

Figure 186.– Concluded.

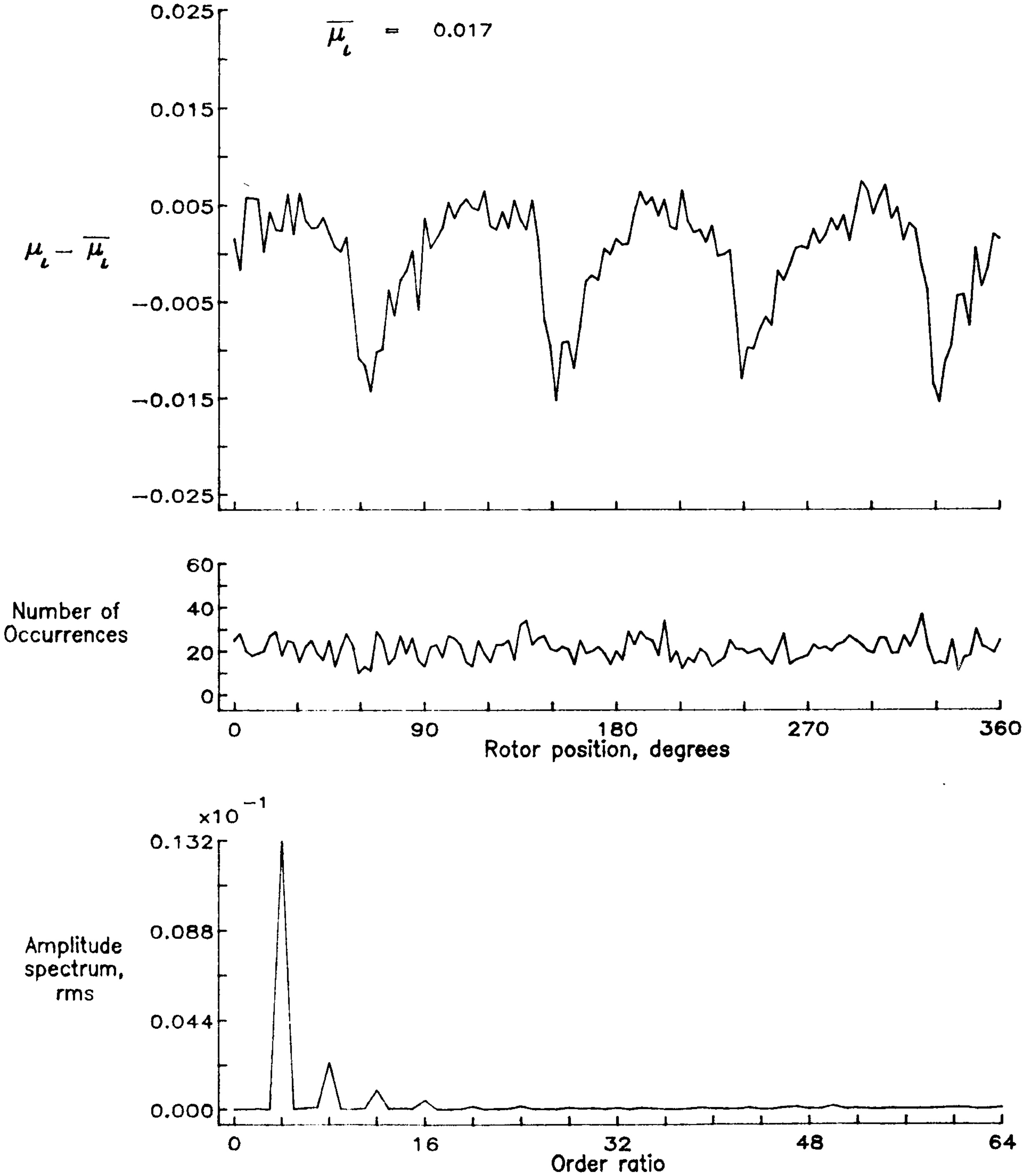

Figure 187.— Induced inflow velocity measured at 330 degrees and r/R of 0.90.

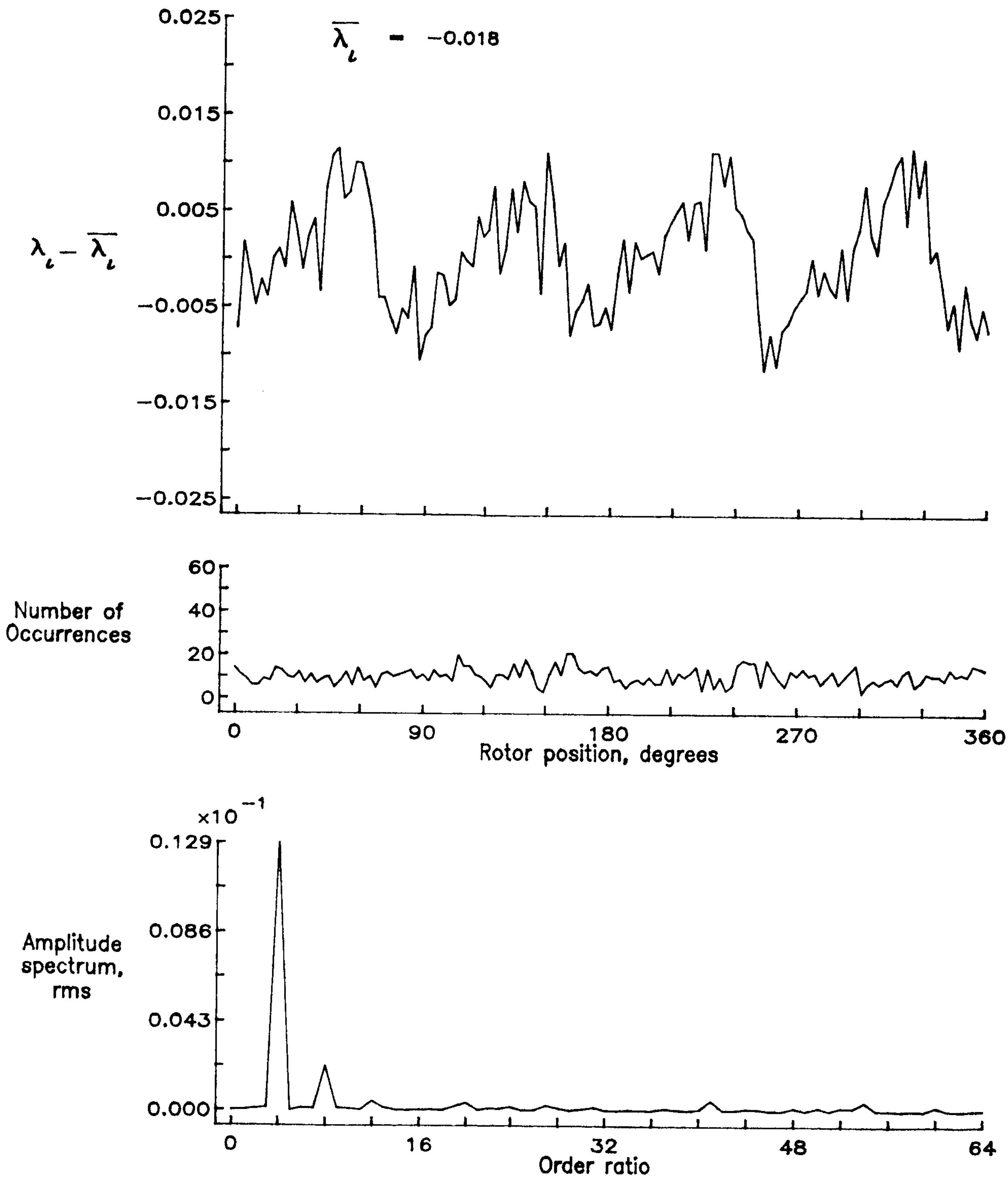

Figure 187.– Concluded.

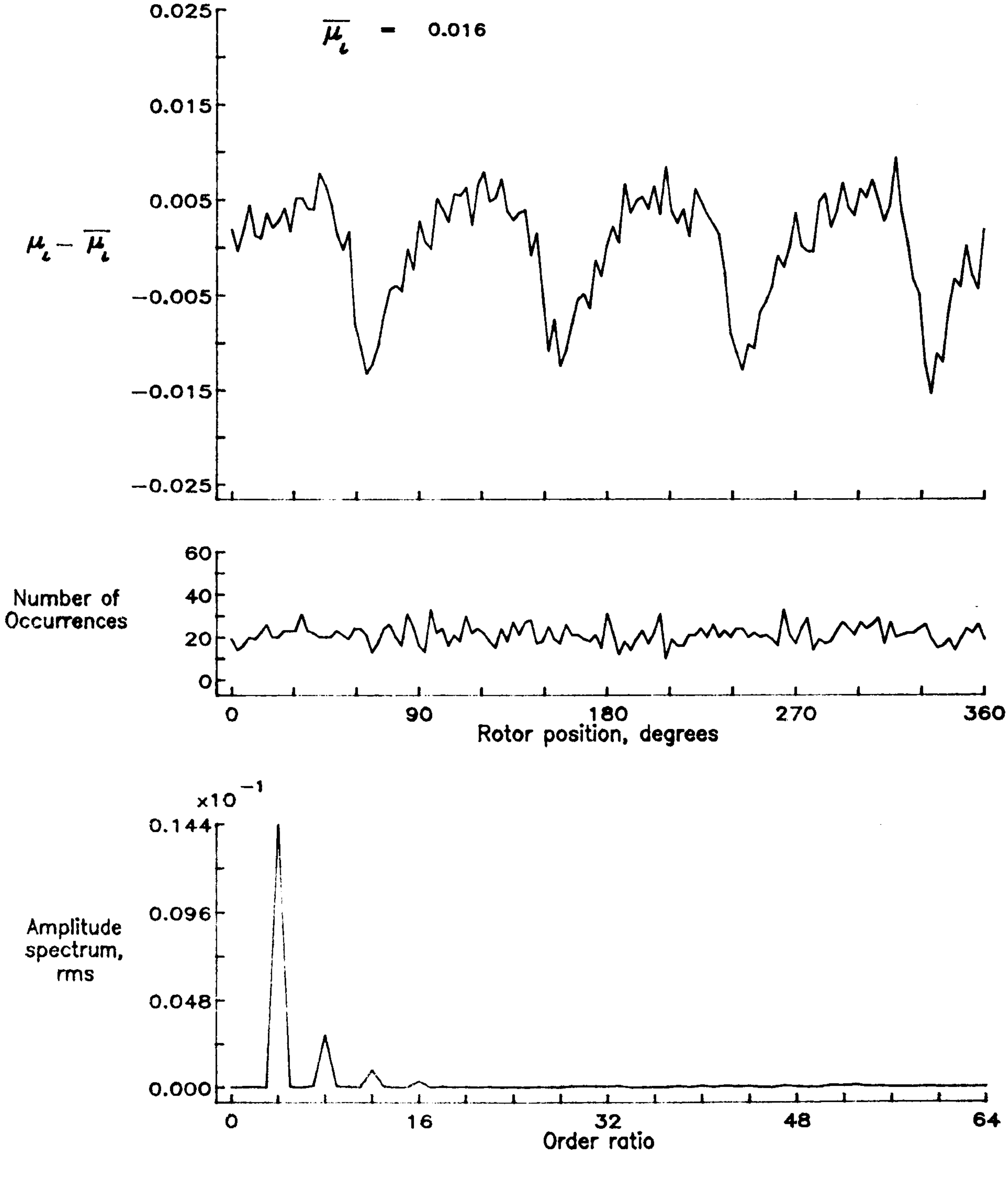

Figure 188.– Induced inflow velocity measured at 330 degrees and r/R of 0.94.

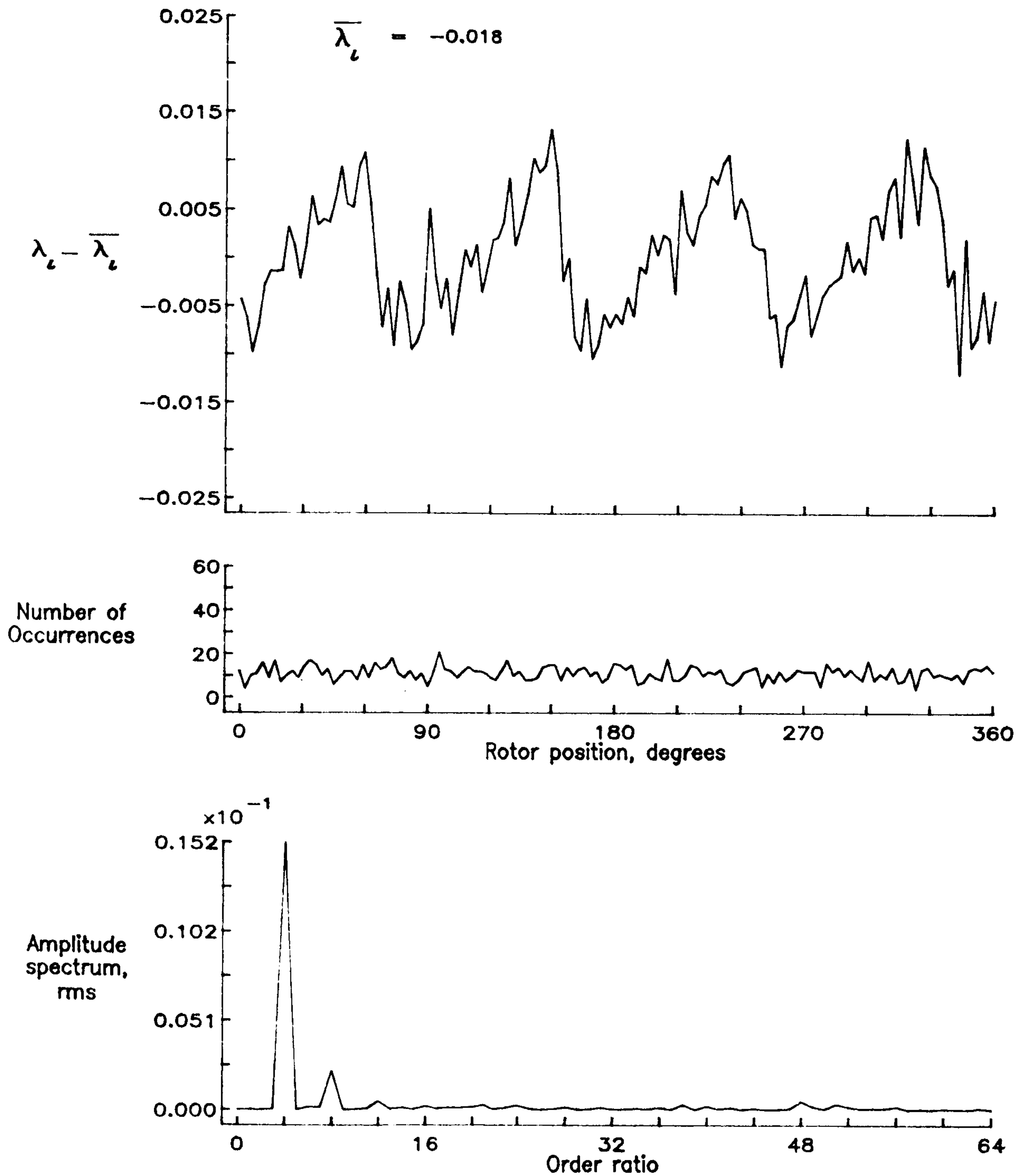

Figure 188.— Concluded.

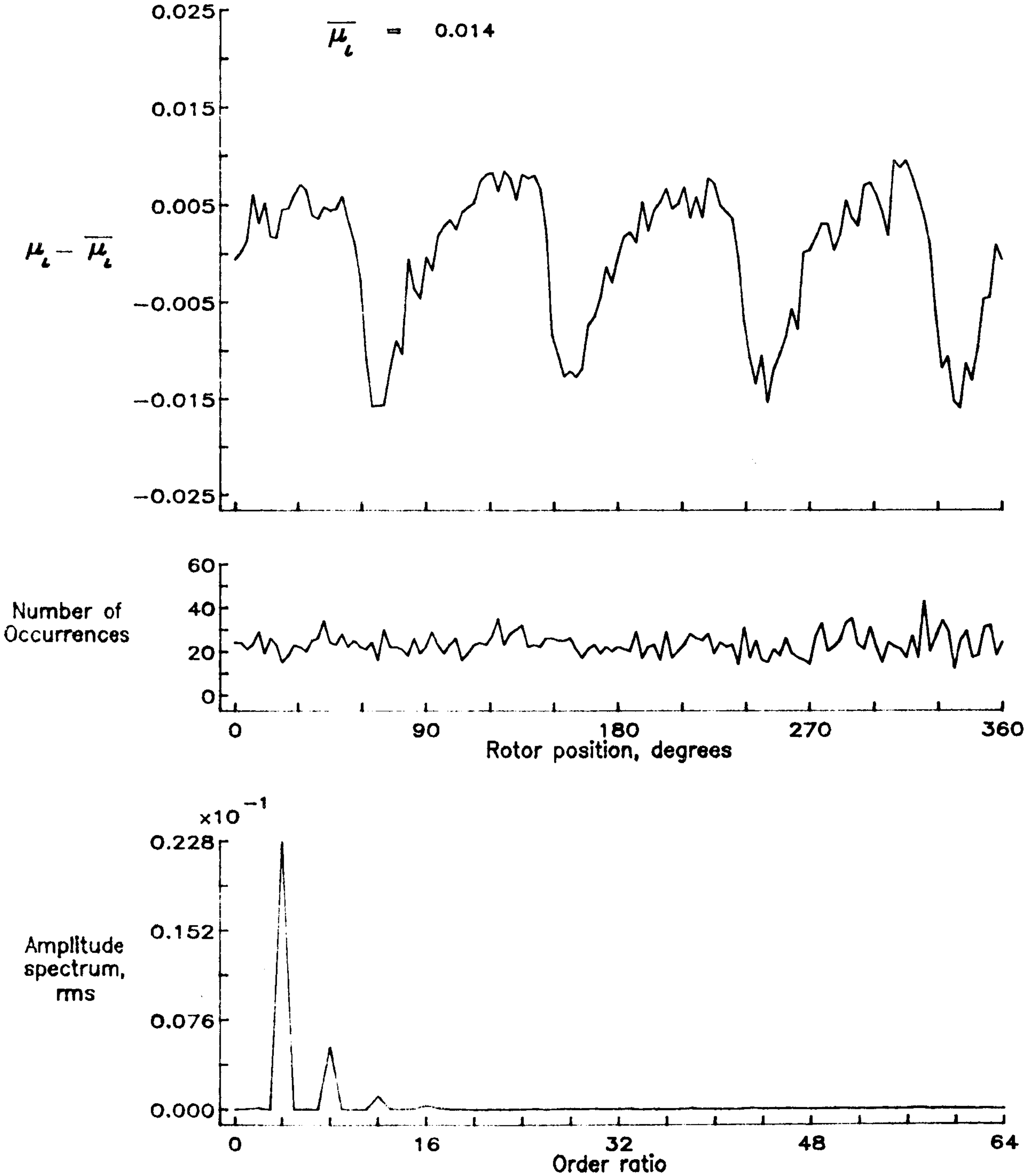

Figure 189.– Induced inflow velocity measured at 330 degrees and r/R of 0.98.

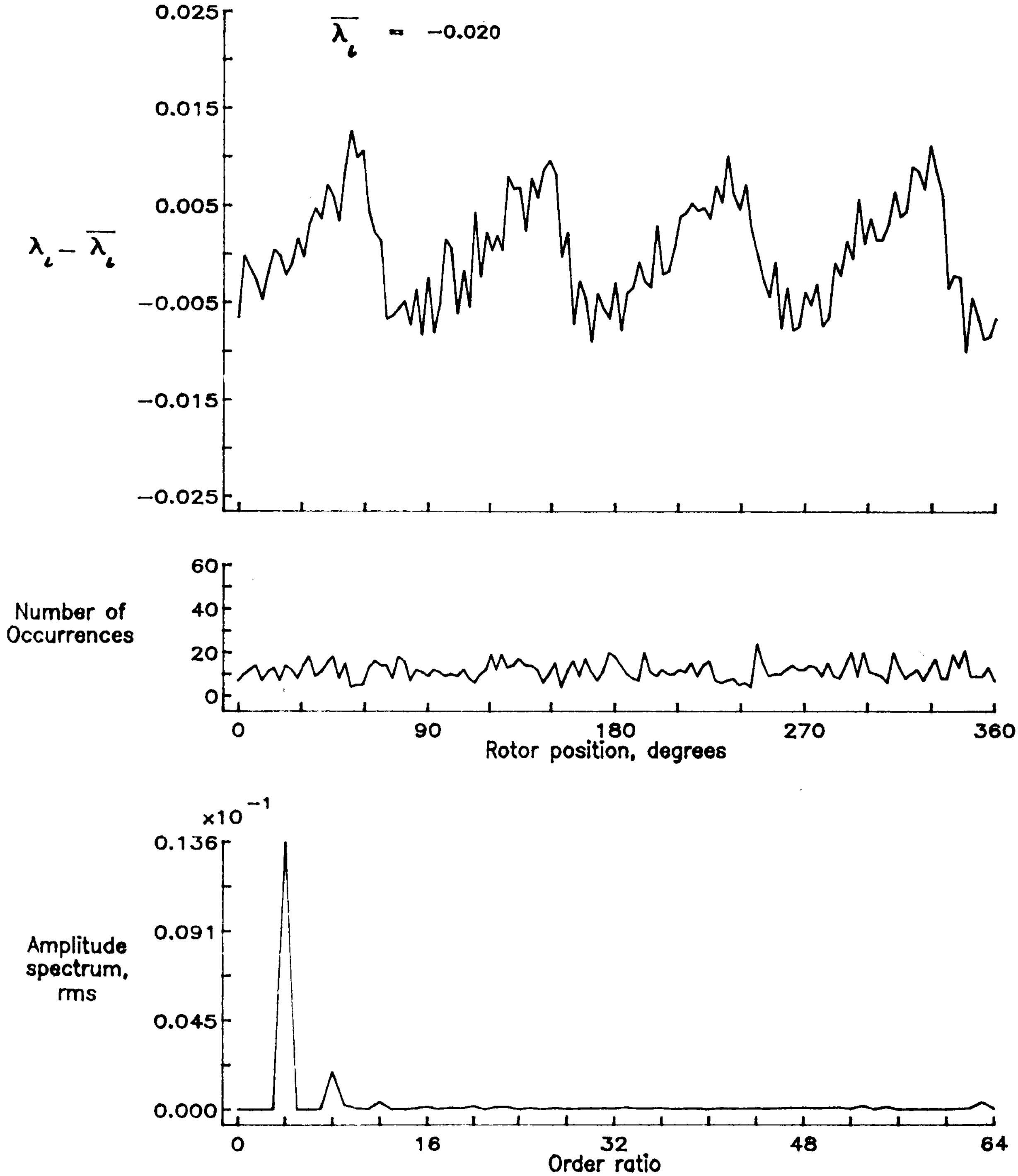

Figure 189.– Concluded.

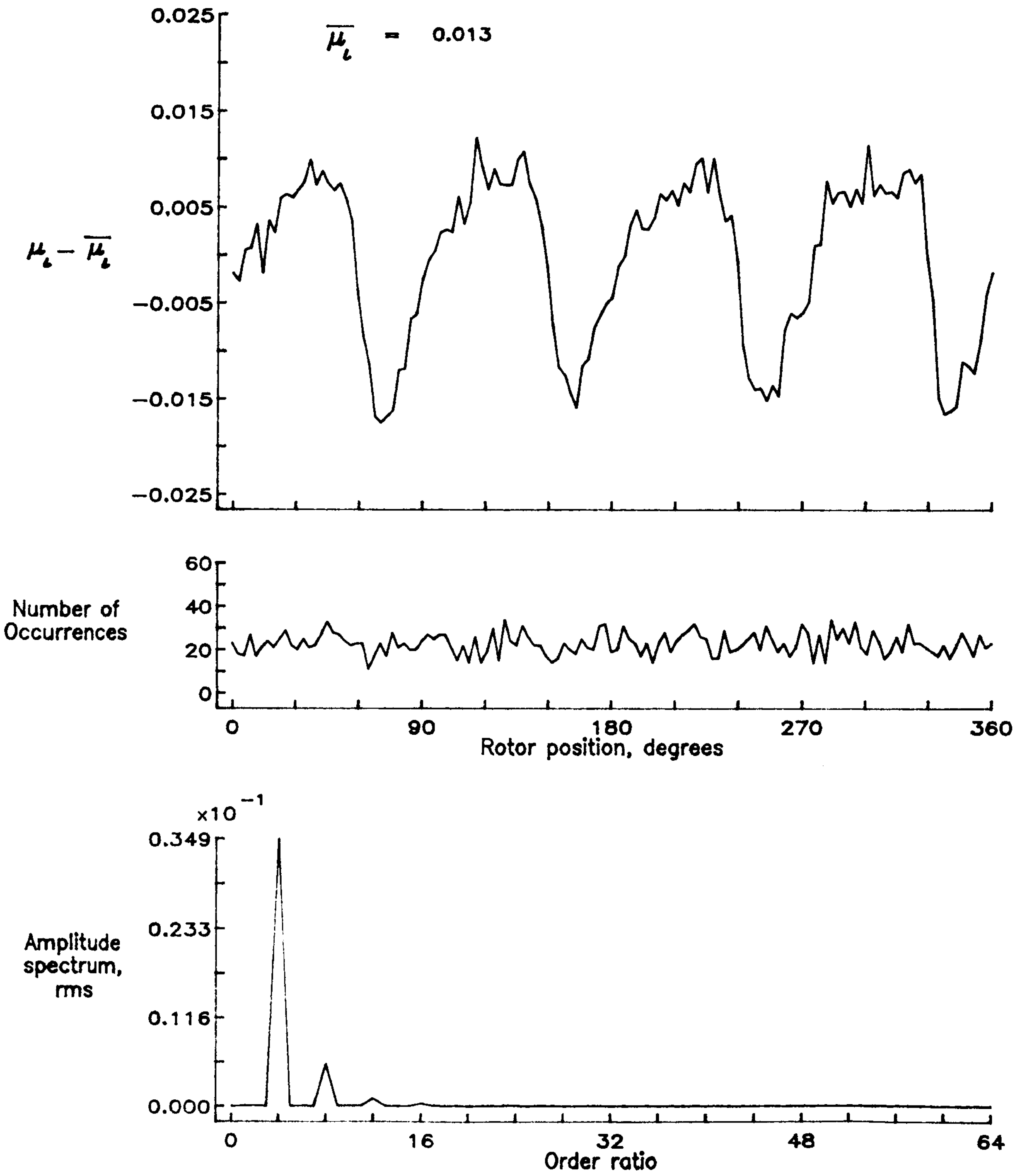

Figure 190.– Induced inflow velocity measured at 330 degrees and r/R of 1.02.

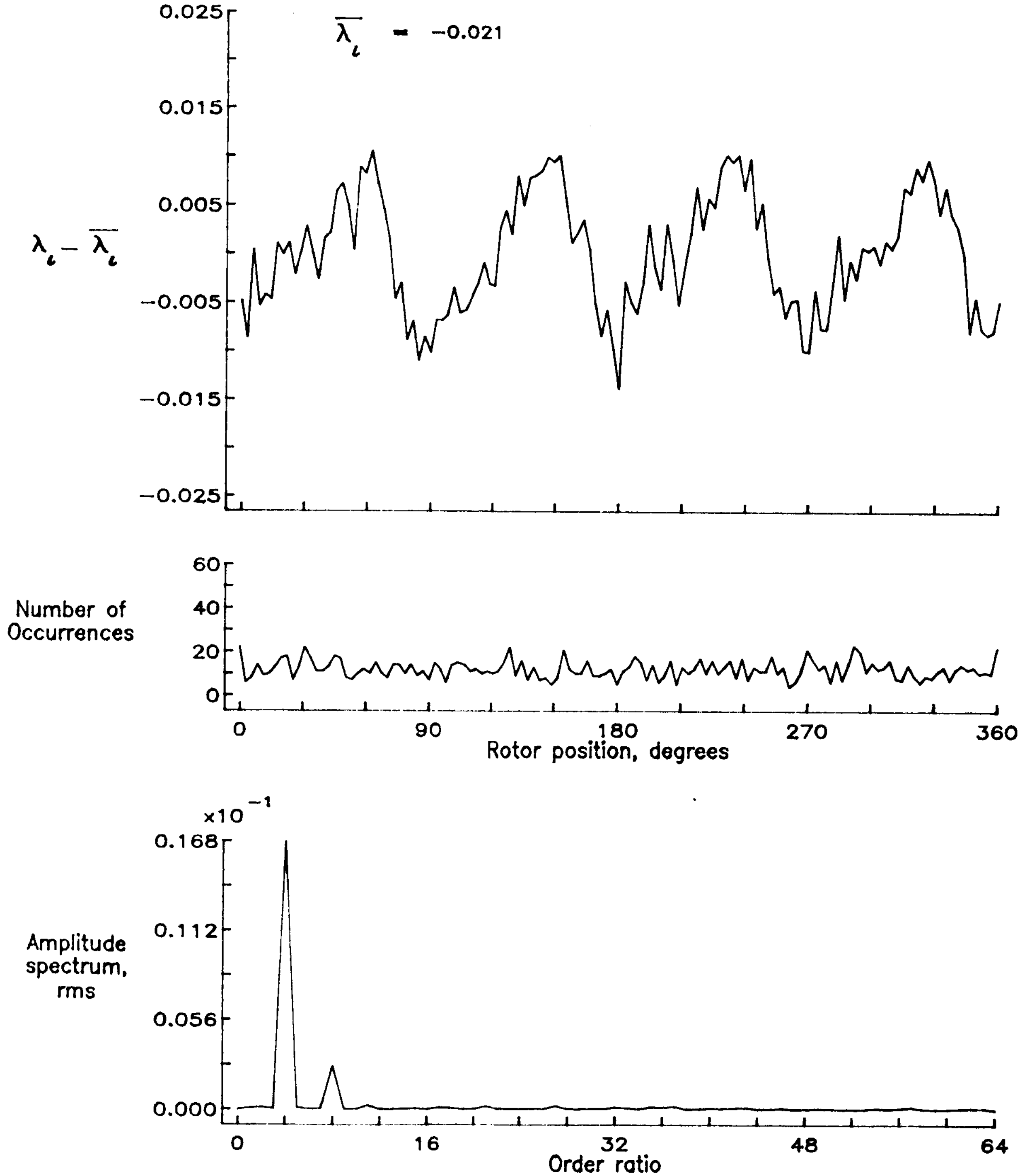

Figure 190.– Concluded.

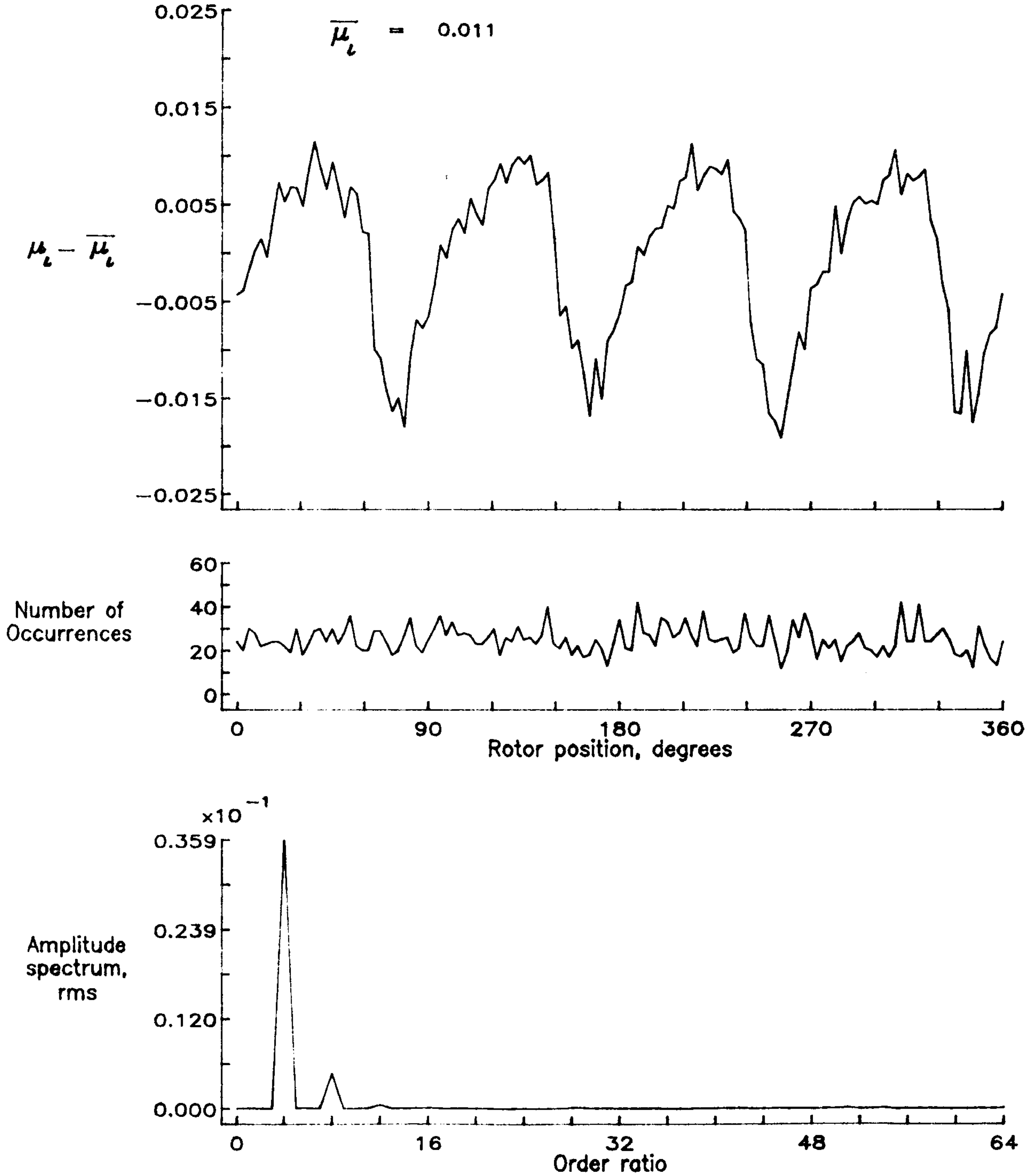

Figure 191.– Induced inflow velocity measured at 330 degrees and r/R of 1.04.

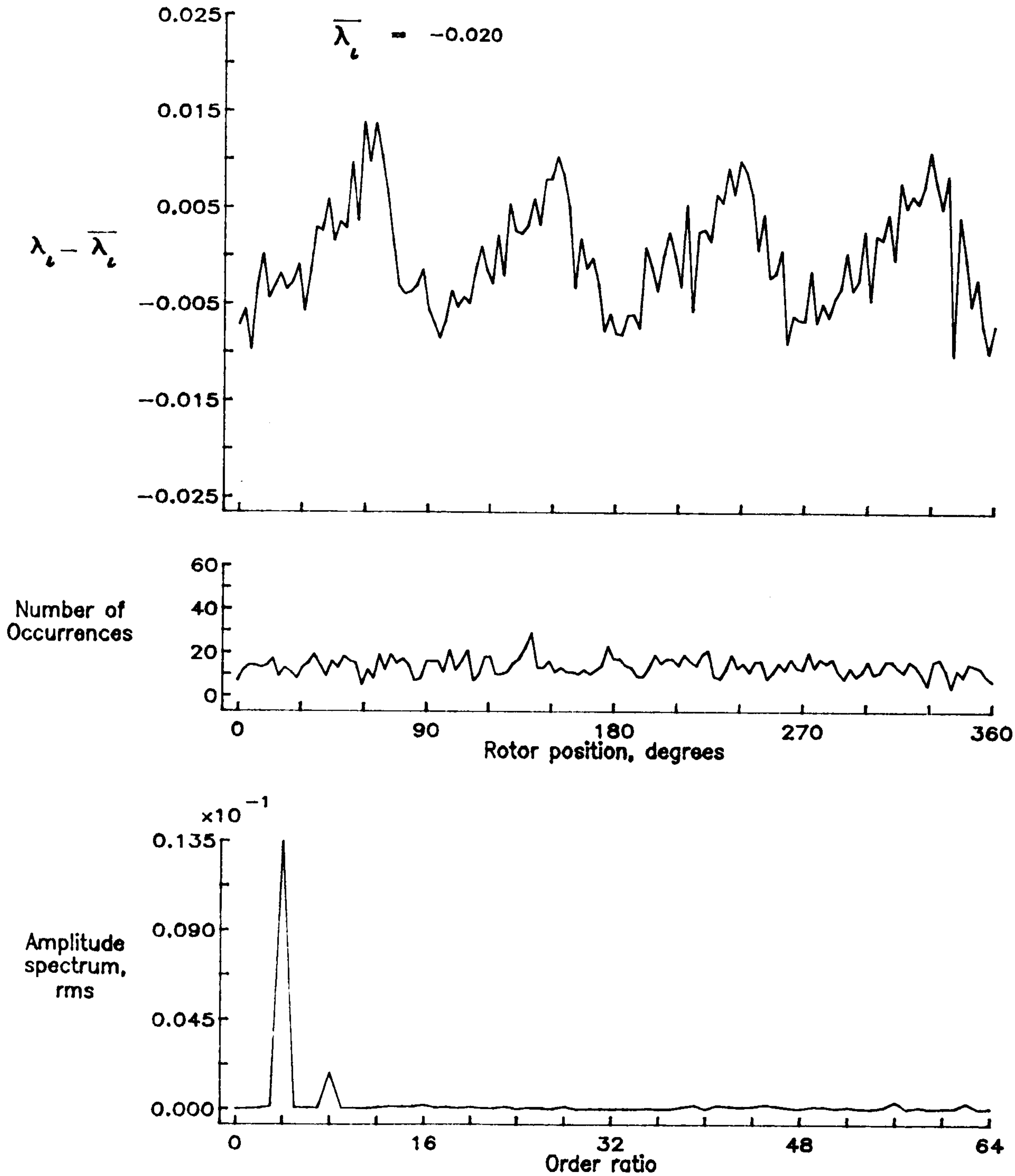

Figure 191.– Concluded.

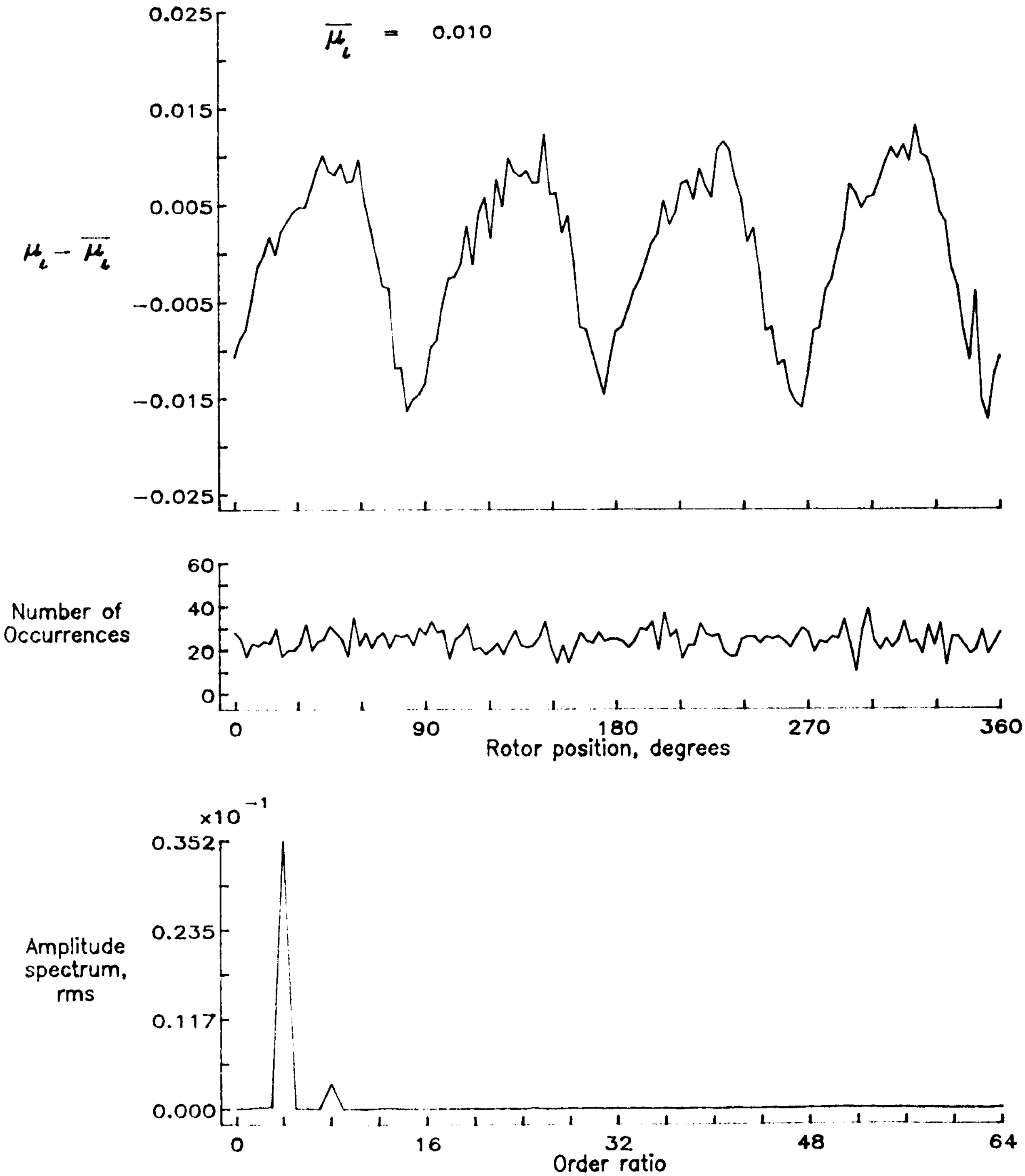

Figure 192.– Induced inflow velocity measured at 330 degrees and r/R of 1.10.

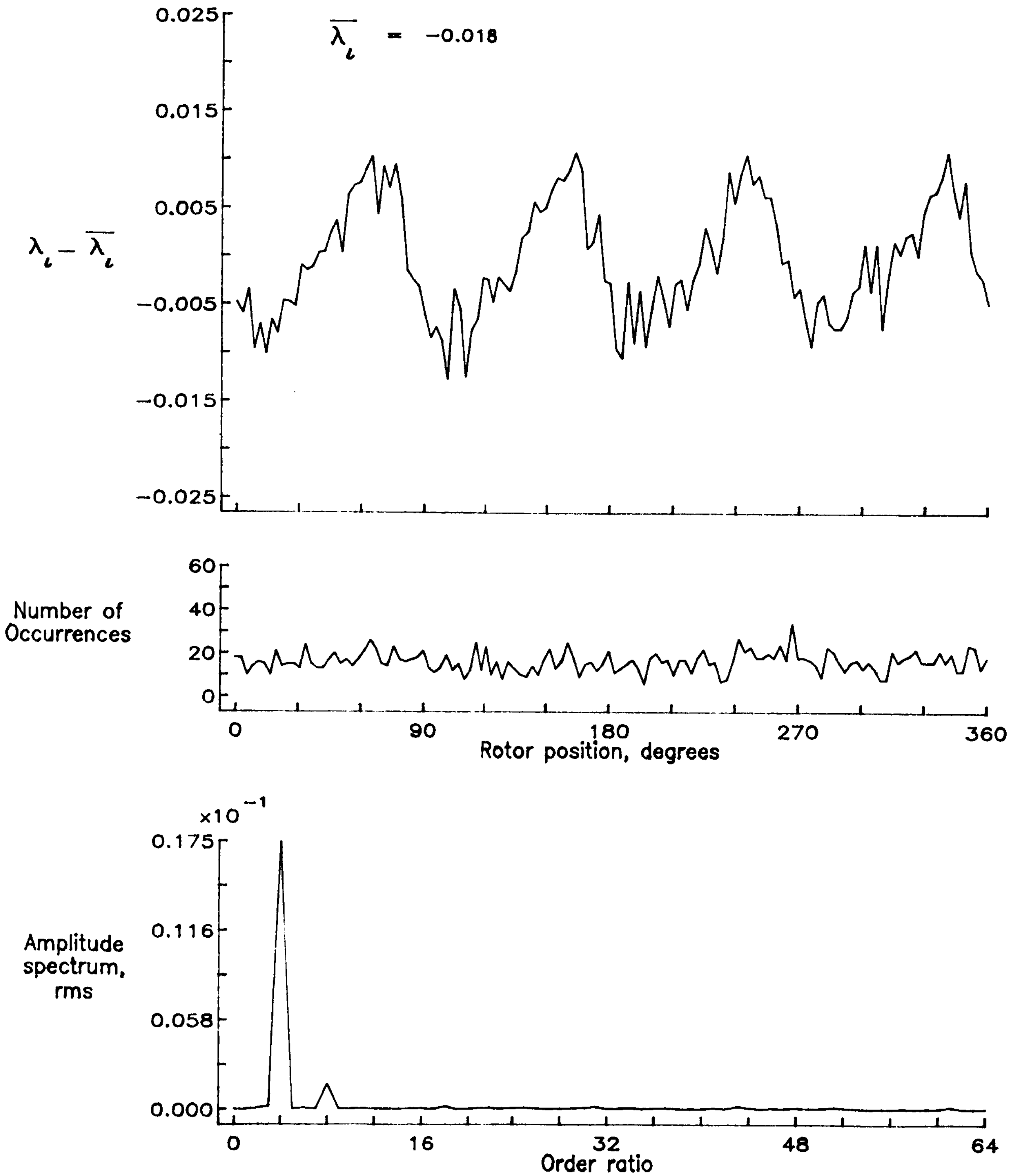

Figure 192.– Concluded.

C-5

Report Documentation Page

National Aeronautics and Space Administration

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-100543 AVSCOM TM 88-B-006		

4. Title and Subtitle

Inflow Measurements Made With A Laser Velocimeter On A Helicopter Model In Forward Flight, Volume III Rectangular Planform Blades at an Advance Ratio of 0.30

5. Report Date

April 1988

6. Performing Organization Code

7. Author(s)

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Richard H. Sailey

8. Performing Organization Report No.

9. Performing Organization Name and Address

Aerostructures Directorate
USAARTA-AVSCOM
Langley Research Center
Hampton, VA 23665-5225

10. Work Unit No.

505-61-51-10

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

National Aeronautics and Space Administration
Washington, DC 20546-0001 and
US Army Aviation Systems Command
St. Louis, MO 63120-1798

13. Type of Report and Period Covered

Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes

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Richard H. Sailey: PRC Kentron, Inc., Hampton, VA

16. Abstract

An experimental investigation was conducted in the 14- by 22-Foot Subsonic Tunnel at NASA Langley Research Center to measure the inflow into a scale model helicopter rotor in forward flight ($\mu_\infty = 0.30$). The measurements were made with a two component Laser Velocimeter (LV) one chord above the plane formed by the path of the rotor tips (tip path plane). A conditional sampling technique was employed to determine the azimuthal position of the rotor at the time that each velocity measurement was made so that the azimuthal fluctuations in velocity could be determined. Measurements were made at a total of 180 separate locations in order to clearly define the inflow character. These data are presented herein without analysis.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Rotor model Inflow Laser Velocimetry	Unclassified - Unlimited Subject Category 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	390	A17